THE BULLETIN

OF THE

AMERICAN CERAMIC SOCIETY

Volume 15 MAY, 1936 Number 5

OTTO SCHOTT

A tribute to this distinguished pioneer German glass technologist is published in this issue on page 169. Dr. Schott, who died August 27, 1935, was an Honorary Member of the American Ceramic Society.

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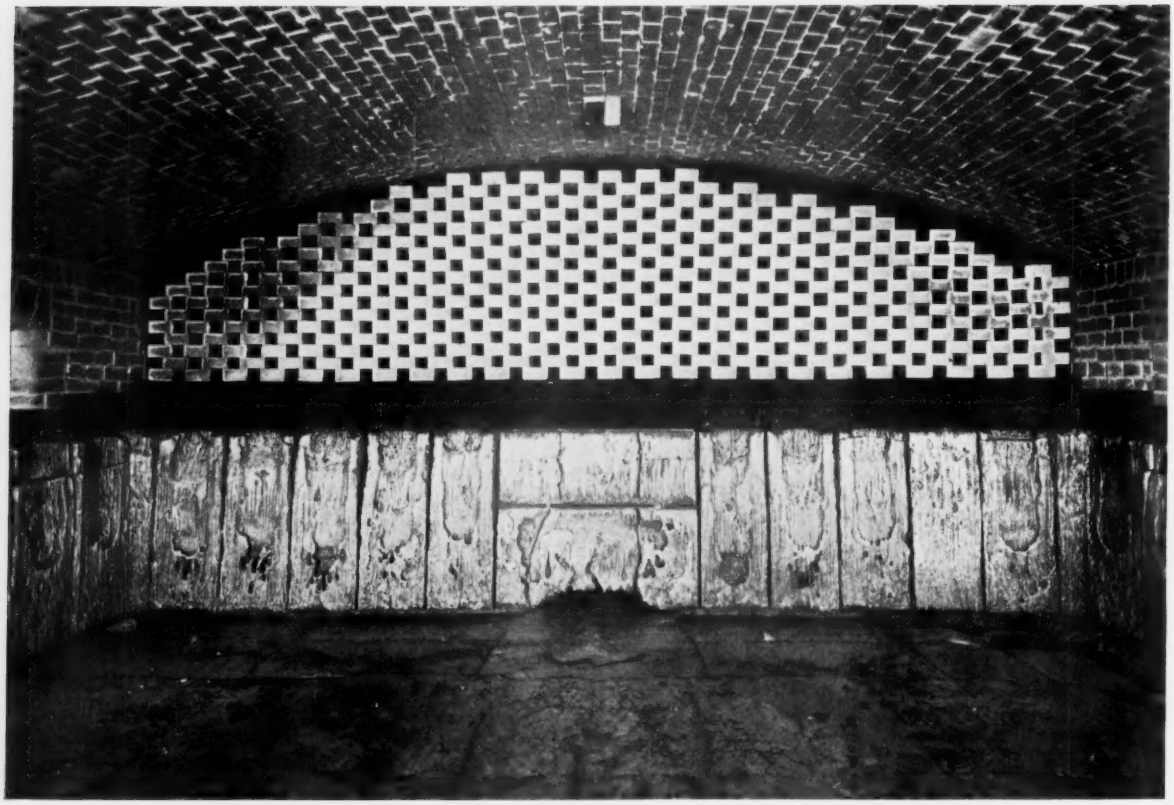

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PAPERS

OTTO SCHOTT: A TRIBUTE*

By Alexander Silverman

I. Historical Introduction

Science probably found its first true application to glassmaking in the field of optical glass. The earliest factory which was successfully operated came into being about 1800 in France, where P. L. Guinand and his son, A. Guinand, directed the enterprise. In 1811 J. Frauenhofer, who later was a pioneer in the German industry, became associated with the elder Guinand and worked with him for two years. The subsequent achievements of Thibeaudeau, Bontemps, Daguet, M. and E. Feil, Mantois, and Parra in this important branch of manufacture are an honor to France.[1] G. Bontemps left France in 1848 for political reasons and associated himself with Chance Brothers of Birmingham, England, where he developed the manufacture of optical glass.

Before this time, Harcourt,[2] an English clergyman, in 1834 had started a series of experiments. Frauenhofer,[3] who died in 1826, had realized that the chemical substances used in the manufacture of glass were inadequate to meet the optical requirements, but he could not get beyond the few chemical oxides then known for the purpose. Harcourt was an ingenious experimenter, utilizing platinum and porcelain crucibles and heating with a hydrogen-air mixture. He discovered the possibility of substituting the oxides of phosphorus and boron for the high melting silica. In 1844 he was cited by the British Association for the Advancement of Science for his trial melts in which he hoped "to compare the chemical constitution with the optical properties of different glasses." In 1862 he established a friendship with the physicist, Stokes, who made the optical measurements. These men realized the significance of refractive index and dispersion. By 1871 Harcourt had tried twenty chemical elements in his melts. Prior to his investigations only the oxides of silicon, calcium, sodium, potassium, lead, and aluminum had been used. Harcourt added those of lithium, beryllium, boron, magnesium, phosphorus, titanium, vanadium, zinc, arsenic, strontium, molybdenum, cadmium, tin, antimony, tungsten, barium, thallium, and bismuth, as well as fluorine compounds. His glasses, however, lacked the homogeneity that was necessary. Though he had prepared one hundred sixty-six prisms, the making of definite measurements was impossible. The glasses were not stable on exposure to atmospheric conditions. His experiments were commendable, but he died without seeing them brought to practical perfection. In other words, he could not bridge the gap between laboratory experiment and actual manufacture.

In 1851 a good borosilicate crown glass was produced by Maës in Clichy. Astronomical objectives made from this glass were exhibited in London in 1851. It was not sufficiently better than glasses previously produced to displace them.

In 1829 the chemist Döbereiner experimented in Jena to replace calcium oxide with barium oxide.

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Contribution No. 309 from the Department of Chemistry, University of Pittsburgh.

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[1] M. von Rohr, *Z. Instrumentenk.*, **29**, 50 (1909).

[2] Stokes, Brit. Assn. for the Advancement of Sci., *Repts.*, 1871–1874.

[3] E. Zschimmer, Die Glasindustrie in Jena, ein Werk von Schott und Abbé. Eugén Diederichs, Jena (1909).

His work is mentioned by Goethe, who constantly interested himself in scientific development. In 1872 Benrath experimented with barium glasses, utilizing the natural carbonate and sulfate, but again the manufactured article failed to materialize.

In summarizing, one may comment that optical glasses were manufactured since about 1800 but that only a few chemical oxides could be utilized in a practical way. This introduction will serve to emphasize the importance of the accomplishments of Otto Schott.

Otto Schott and His Family

It has been difficult to obtain material of a personal nature concerning Dr. Schott, but the writer has been fortunate in receiving interesting information through the courtesy of Dr. Erich Schott, one of his sons.

Friedrich Otto Schott[4] was born December 17, 1851[5,6] or 1852[7] in Witten, Westphalia, Germany. He was the son of Simon and Karoline Hahne Schott. Inasmuch as both of the parents' families were descendants of glassmakers, Otto Schott enjoyed an early environment of glassmaking. The details of this background have already been published.[8] Simon Schott established the glass factory of Haarmann, Schott, and Hahne in Witten, Germany. Simon Schott, a window-glass worker, obtained his experience in glass factories in Haarburg, Germany, and in Lyons and other French centers. His own enterprise was a success. Since Otto Schott interested himself along other fields of glassmaking and his brothers suffered early deaths, Simon Schott's factory was taken over by others after his death.

Otto Schott had five brothers and one sister. He was the second youngest. His brothers were engineers and glassworkers but, as has already been stated, all died as comparatively young men. Only the sister reached a fairly old age. She was a charming hostess, and the writer recalls her from his visit to Jena in the summer of 1928.

Dr. Schott married Kathe Pielke, who died January 19, 1926. They had five children: one daughter, Eva, married Professor Gerland, a jurist; a son, Rolf, killed during the World War; Dr. Erich Schott in the Jena Glass Works; a daughter, Daniela, whose late husband was a professor of medicine; and the youngest son, Dr. Gerhart Schott, who is associated with his brother Erich in the Jena factory. The children were born about two years apart, from 1887 to 1895.

Otto Schott was a veritable fiend for work, and what rare periods of freedom he possessed were taken up largely with studies and plans. And yet with all this, he was an unusually lovable father. His children will never forget the fairy tales which he related, many of which were the fruit of his own vivid imagination. He was most thoughtful of the children and they have no recollection of his ever having been angry with them at any time. Though not a disciplinarian, he held their greatest respect. He was a firm believer in freedom for children, in letting them follow their natural inclinations, and he was opposed to the idea of constantly reminding them of duties and behavior.

Dr. Schott's chief recreation was walking, a practice which he followed throughout his life. It was usually his custom after luncheon and before returning to the factory to walk through the woods for an hour or two. If one wanted to confer with him when his mind was at ease, this was the occasion which was invariably chosen.

Dr. Schott was keenly interested in art. He had a valuable collection of Greek vases and other antiques which he collected on his frequent business trips through the south of Europe. He also interested himself in old paintings of which he had a considerable gallery. He loved music, although he never learned to play an instrument. His knowledge of musical compositions was remarkable, and even in advanced age, some weeks before his death, he would whistle melodies from the operas of Mozart and other masters. He was extraordinarily happy when there was a gathering at his home for a musical evening.

Schooling and Early Work

Otto Schott attended the public school and Hagener trade school in Witten. He later studied in the Technische Hochschule in Aachen and at the Universities of Würzburg and Leipzig. At the University of Jena he obtained the degree of Doctor of Chemistry in 1875 for the presentation

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[4] Meyers Konversations-Lexikon, 5th ed., Vol. 15, p. 616 (1897).
[5] "Dr. Otto Schott," *Glastech. Ber.*, **4,** 41 (1926).
[6] F. Auerbach, Dass Zeisswerk und die Carl-Zeiss-Stiftung in Jena, 4th revised ed., Jena (1914).
[7] Reichshandbuch der Deutschen Gesellschaft, **2,** 1700, Berlin (1931).
[8] H. Kühnert, "Otto Schott," and E. Berger, "Otto Schott's Work," *Z. tech. Physik*, **17,** 1–11 (1936).

of a thesis on "Imperfections Encountered in the Manufacture of Window Glass."

While a student, he spent his summers as a volunteer worker in a chemical factory near Hagen, to which he was appointed chemist after graduation. He was sent to England, Scotland, and France to study chemical processes which were in operation there. During 1877 and 1878 he made several trips to Spain, the first to equip a chemical factory in Oviedo and the second to build glass furnaces near Santander.

During the years immediately after he obtained his degree, he published an extensive treatise on hard glass under a subsidy of the Berliner Gewerbverein, for which work he was awarded a prize. Another treatise was also brought out entitled, "Beiträge zur Kenntnis der anorganischen Schmelzverbindungen," which resulted from an investigation of the solubility of chlorides, fluorides, sulfates, and carbonates in molten sodium chloride and other fused solvents to determine their reactions. These experiments led him to make a further study of reactions in the fused state. His ambition was to establish a knowledge of reactions through fusion, just as inorganic chemistry had developed a systematic study of reactions between inorganic substances in aqueous solution. This objective resulted in his many valuable contributions to the chemistry of glass technology.

In 1876 there was an international exhibition of scientific apparatus in London which Professor Ernst Abbé of Jena attended. In 1878 Abbé published a report on this exhibition[9] from which the following is quoted.

> The future of the microscope as to further improvement . . . seems to lie chiefly in the hands of the glassmaker . . . for the removal of the secondary spectrum and a greater variability in the relation between the dispersion and mean index. There is now a definite hope that these conditions will sooner or later be satisfied, and the way thus be opened to radical improvement in the microscope and other optical instruments. The limitations observed in the connection between the refraction and dispersion in existing glasses must not be regarded as a natural necessity, for among both natural minerals and artificial products there are plenty of transparent substances which are known to have widely different properties as to refraction and dispersion. . . . The uniformity shown by existing glasses in their optical qualities is probably chiefly due to the very limited number of materials hitherto used in their manufacture. Beyond silicic acid, alkali, lime, and lead, scarcely any substances have been tried, except perhaps alumina and thallium. When this narrow groove is left and a methodical study, on an extended scale, is made of the optical qualities of chemical elements in combination, we may anticipate with some confidence a greater variety in the products.
>
> Unfortunately there seems to be little hope of material progress in this direction in the immediate future—a state of things very detrimental to the interests of science. The manufacture of optical glasses has for a long time been almost a monopoly; so few have been engaged in it that there could be no real competition. . . .
>
> It is scarcely to be expected that private initiative, without strong backing, will supply the necessities of the case in time to prevent things from becoming much worse. The difficulties connected with such undertakings are so great, the initial outlay required is so heavy, and success, if attained, lies so far in the future, that there is little inducement to enterprise. . . . . .
>
> This is a field in which learned societies, in a position to furnish material help for scientific requirements, could discharge a peculiarly useful and grateful office; for very important and diversified interests are dependent on the glassmaking industry, its continued efficiency, and its further improvement. It is not microscopy alone that is here affected, but all sciences and arts that need optical appliances.

Early Experiments

Abbé's paper made a profound impression on Otto Schott.[10] Uninformed regarding earlier experiments with lithium compounds, he was inclined to try these in optical glass melts.[3] His first trials were conducted in Witten, where he resided. He used a small charcoal furnace and made melts in preheated, covered Hessian crucibles. The dust from the fuel and the impurities in the clay contaminated the melts. A study of clays resulted in an improvement of the crucibles, but the glass yield was small, only twenty to sixty grams.[6]

In May of 1879 Schott wrote to Professor Abbé asking that he study the optical properties of the lithium glasses produced. The specimens were so full of cords that Abbé could not use them. Undeterred, Schott sought means of stirring the tiny melts and finally succeeded in locating porcelain tubes of the type used in the large German tobacco pipes. The results were successful and produced more homogeneous glasses. Further disappointment, however, was in store for him. The lithium glasses did not possess properties sufficiently different from older types. Schott then conceived the idea of working with the oxides

[9] E. Abbé, "Die optischen Hilfsmittel der Mikroskopie," *Ber. über d. wissensch. Appar. auf d. Londoner intern. Ausstellung i. J. 1876*, **1**, 417, Brunswick (1878).

[10] H. Hovestadt, Jena Glass and Its Scientific and Industrial Applications. Macmillan & Co., Ltd., London (1902).

of phosphorus and boron and again communicated his ideas to Abbé. It is on record that the correspondence by letter and telegram between the chemist and the physicist was voluminous.

The time came when a conference seemed desirable. Prior to this time, Schott had already studied the optical properties of many transparent minerals. As the result of his untiring investigations, he obtained an insight into the problems which confronted him, which has been referred to by Zschimmer[3] as "an ability to look into the very heart of a glass." The young chemist continued his investigations and in January of 1881 arranged to visit Abbé. The latter anxiously awaited his arrival. He was living in the Schiller home in Weimar, near Jena. Finally toward midnight, there was a knock at the door. Abbé appeared in his night shirt, smoking one of those very pipes whose porcelain stems had served Schott so well. Schott received a hearty welcome, and the men sat in the parlor discussing phosphate glasses until three o'clock in the morning, when Mrs. Abbé, who could no longer stand the enthusiastic conversation which penetrated the thin ceiling between the parlor and her bedroom, shouted, "I can't sleep on account of that damn phosphoric acid!" The meeting adjourned instantly.

Schott returned to Witten, continuing his experiments on the phosphate glasses and submitted specimens regularly to Abbé, who made the optical measurements. Unfortunately, the first results were again discouraging. Abbé, however, wrote, "Your experiments indicate a great variety of possibilities for optical properties of glasses (of which Schott had already prepared over one hundred) and your number 12 (a beryllium-phosphate crown) shows a dispersion of 20% less than the lightest crown glass known heretofore." The small melts were continued with the phosphorus and boron glasses, but better facilities were necessary.

Fletcher, an Englishman, had devised a furnace operating by a gas-air blast which could produce a temperature of 1500°C, or higher, and yield an oxidizing or reducing atmosphere as required. Melts of 100 to 150 grams were possible, and the glass could be stirred so thoroughly that good-sized homogeneous masses were available for optical study. The problem of small melts had at last been solved.

Work proceeded with glasses containing boric acid with barium, strontium, and thallium oxides, respectively. Regarding the last two, Abbé reported in October of 1881, "so far as achromatism is concerned, I consider that the last two glasses offer the solution."

In 1882 Schott moved to Jena and, with the cooperation of Carl Zeiss and his son, Roderich Zeiss, planned melts which would yield 10 to 15 kilograms of glass. The planning was simple, but the financing of larger scale operations was another problem. An appeal was made to the Prussian Ministry of Education through political friends of the scientists, and a grant of 60,000 marks was finally obtained for the construction of an experimental plant in Jena. The ministry wished to place the laboratory in Berlin, but the persistent reluctance of Schott to separate from Abbé won a decision for Jena and the researches were continued there.

Laboratory of Schott and Genossen

In 1884 the laboratory of Schott and Genossen was in operation and the first unit of the Jena factory was built. The partnership consisted of Ernst Abbé, Otto Schott, Carl Zeiss, and Roderich Zeiss. By September of 1884 the construction was complete, and on a mild evening, so it is related by Mrs. Abbé, the furnaces were fired. "It was my good fortune to start the fires. The entire personnel was in attendance. A large table was spread and we celebrated. It happened to be the anniversary of the victory at Sedan, which terminated the Franco-Prussian War. The people of Jena were celebrating a double event with great bonfires on the hills and the ringing of the bells; and so we dedicated the plant by eating ravenously of the sausages and potato salad, and the generous drinking of wine."

The manufacture of optical glass was soon under way. The old glasses, discolored by greenish and yellowish casts, were supplanted by colorless products. They received varied application from the smallest microscope objective to large telescope reflectors. These were not immediate results, but the consequence of constant research and its application. A catalog, published in 1923, lists one hundred and sixteen different optical glasses, various types of crown and flint, including fluoride, phosphate, boron, barium, zinc, and other types.

Schott's investigations were not limited to the production of glasses from a chemical standpoint. He soon realized that good service depended on

proper annealing,[11] and he studied the softening points and annealing ranges of his various products. The density of each glass was noted. He discovered that density was a cumulative factor depending on the chemical substances employed, that each chemical oxide had a value, and that the density of the glass was additive.

It was desirable to know the mechanical properties[12] of glass. This led to the study of the relationship between composition and strength, as well as elasticity. Modulus of rupture was calculated and determined. Information about thermal properties[13] was wanted and calculations were formulated which made the estimation of the cubical coefficient of expansion[14] and thermal endurance possible. The Schott and Winkelmann factors for calculating cubical expansion were in use until 1920, when English and Turner started a series of investigations which resulted in revised values.[15]

In 1891 Schott began his investigations on the thermal expansion of cased and "compound" glass.[16] He had already developed the famous 16^{III} and 59^{III} crystal glasses[17] for thermometers, in which he demonstrated that a single alkali like sodium or potassium carbonate in the glass batch would prevent the shifting of the zero point in thermometers on aging, a tendency which is pronounced in glasses containing mixed alkalis. The backing of the thermometer with a dense opal glass to facilitate reading introduced the new difficulty, namely, the expansion problem. It was solved by applying his thermal expansion and annealing data. Perfecting the glasses and introducing inert gases above the mercury resulted in a thermometer which could be used for temperatures up to 500°C.

In compound glasses for steam boiler gages, Schott deliberately produced a strain between the inner and outer crystal layers, whose concentric effect made the tubing withstand higher pressures. Later he used a zinc glass and resorted to the case-hardening principle now so generally applied in the manufacture of tempered glass.

In 1892 he gave the scientific world the Jena borosilicate laboratory ware,[18] which was a great advance from the standpoint of resistance to thermal change, shock, and chemical action. With the advent of the Welsbach mantle for gas lighting, the common lime chimneys previously employed for oil lamps shattered readily under the intense heat. Schott first used the laboratory glass for making these chimneys, later enlarging them and melting air holes into the base of the chimneys[3] so that combustion might take place inside and outside of the mantle and thus equalize the pressure upon the fragile incandescent cone.* Then came his heat-resisting opal glass, which accomplished the same purpose as the crystal, and prevented eye-strain by concealing the mantle and diffusing the light.

Upon the discovery of X-rays by Röntgen, Schott gave his attention to the preparation of a glass especially transparent to the new rays,[19] learning about the efficiency of elements of low atomic weight. The elements of high atomic weight were utilized in glasses to absorb these rays and protect the operators. He also worked on the dielectric constants of different glasses toward their utilization for insulating purposes. Later came his glass for mercury-vapor lamps, the mercury-arc rectifiers for converting alternating current to direct current, and the direct-current meters which depended on electrolysis of a conducting solution with the generation of hydrogen to measure current consumption.

By 1909 the fruits of Schott's labors were in full evidence. The factory in Jena was producing optical and thermometer glasses, chemical glassware, electric lamp bulbs, and a variety of other products. There were eight buildings which housed furnaces holding approximately one hundred pots, and the company employed more than one thousand workmen. In addition, there was a gas plant, a power plant, the refractories unit, where pots not only were made by hand but cast from a slip, the machine shop, a paper factory, a carpenter shop and box factory, and a railway and mechanical conveying system.

[11] O. Schott, *Z. Instrumentenk.*, **11,** 330 (1891).

[12] A. Winkelmann and O. Schott, "The Elasticity and the Tensional and Compressive Strength of Various New Glasses, in Their Relation to Chemical Composition," *Ann. Phys. Chem.*, **51,** 697 (1894).

[13] A. Winkelmann and O. Schott, "The Thermal Resistance-Coefficients of Various Glasses in Their Relation to Chemical Composition," *ibid.*, **51,** 730 (1894).

[14] A. Winkelmann and O. Schott, "Calculation of the Cubical Coefficient of Expansion of Glass from the Chemical Composition," *ibid.*, **51,** 735 (1894).

[15] Sprechsaal Kalender, p. 89, Coburg (1935).

[16] O. Schott, Vortrag im Verein z. Beförd. des Gewerbfl., April 4, 1892, p. 11.

[17] O. Schott, "Researches on Thermometer Glasses," *Z. Instrumentenk.*, **11,** 334 (1891).

[18] A. Winkelmann and O. Schott, *Z. Instrumentenk.*, **14,** 6 (1894).

[19] O. Schott, Beiblatt, *Z. ibid.*, No. Heft 13 (1899).

More recently the researches at Jena have resulted in special glasses for the absorption or transmission of ultra-violet or infra-red and the absorption or transmission of special regions in the visible spectrum.

In 1889 Professor Abbé was instrumental in the formation of the Carl Zeiss Foundation, which was incorporated on May 19 of that year. The magnanimity of this act is beyond appraisal. It assured a definite wage for the workers, provided insurance against loss of time through illness and for the families of workers during illness or in the event of death, and established an eight-hour day. Abbé stipulated that a limited portion of the profits should accrue to the founders and their administrative successors and that the workmen should be the beneficiaries. By 1891 the Jena factory and the firm of Carl Zeiss came under the Foundation with the exception that Otto Schott retained a special membership in the firm. In 1919 he turned his interests over to the Foundation and thereafter served as technical director until his retirement from active service in 1927. He continued his interest in the plants which operated under the Foundation to the very last.

Otto Schott was rightfully the recipient of many honors. He received the honorary degree of Doctor of Medicine (Jena) and the degree of Doctor of Engineering. He was a member of the Prussian Academy of Sciences and an Honorary Member of the Deutsche Glastechnische Gesellschaft and of the American Ceramic Society. He was awarded the Liebig Medal of the Verein Deutscher Chemiker. As might be expected, he was an honorary citizen of Jena.

Appendix: Personal Recollections of Dr. Schott

Dr. Silverman's Visit in Germany

During the summer of 1928, I visited Dr. Schott in Jena. Never having met him, I was pleased to receive a telegram in response to one sent from Florence, Italy, to the effect that I would be welcome. Upon my arrival during the latter part of an afternoon, I was received by Dr. Schott, his sister, and his two sons and their wives. A table was spread for "kaffee" and an immediate sociability and friendship developed. After coffee and cakes, we repaired to the attractive garden in the rear of the home where the family and Dr. Schott's dachshund posed for movies, apparently the only motion pictures ever taken of him. Then the two sons and their wives motored me to Weimar, where the Schiller house in which Abbé lived and the homes of Goethe and Liszt are located. The next day I was taken through the giant factory at Jena, that great monument to Otto Schott and his associates.

The cordial reception of a much younger man, who was a stranger, except perhaps for a small contribution in the same field in which Dr. Schott was interested, indicates his hospitable nature. There was no ostentation, no air of superiority, but rather a humble bearing. Dr. Schott was a modest, retiring individual, as is evident from the limited biographical material which is available.

To learn about Dr. Schott's visits to America, the writer communicated with all of the glass technologists of that time who were likely to have met him. Their impressions are quoted directly.

Dr. Schott Visits Edward Bausch

Edward Bausch of the Bausch and Lomb Optical Company comments: "Dr. Schott made two visits to this country, the first one alone in 1909, departing November 6, but the date of his arrival we can not find. At various periods during this visit he lived with me. During this time he visited Chicago, Washington, and made several trips to Corning, N. Y., where, he informed me at the time, they were talking over business matters. His second visit was with Mrs. Schott, beginning April 5, 1911, and leaving again May 20. A good part of this visit was spent on the Pacific Coast. I was abroad during that time, but I believe he also visited Corning while here.

"Regarding my impressions of Dr. Schott, I may say that I met him first on one of my visits to Jena, in 1891, the year in which I first met Dr. Abbé, with whom we made our first license agreement for the manufacture and introduction of Anastigmat lenses in the United States, this to be followed by another license agreement for the manufacture and introduction of the Prism Binoculars in 1903. Dr. Schott was also a member of the Board of Trustees of Carl Zeiss until 1907 or shortly thereafter. During these years and until 1914 we purchased almost all of our optical glass from Schott & Genossen, and I made many visits to the glass works and saw its gradual development into the monster establishment which it became. During my visits there and his visits here we spent many hours together. He was unobtrusive, quiet in speech and manner, thoroughly honest and kindly. His habits and manner of living were very simple, and he would not allow these to change with increasing prosperity. While the relations between himself and his employees were exceedingly friendly, the revolutionary party following the war gained control of his plant and temporarily dispossessed him of it. I understand that he took this very much to heart and that it shattered his health. This showed itself on my last visit to him in 1934."

Dr. Sullivan's Comments

Eugene C. Sullivan of the Corning Glass Works comments: "Dr. Schott's first visit to Corning took place some twenty-five years ago and I recall his simplicity and friendliness of manner and his keen interest in all details of glass manufacture, characteristic of which was his insistence on climbing, at some risk from falling glass and other mishaps, a high, somewhat rickety, wooden tower used in those days for the vertical drawing of thermometer tubing, for the purpose of inspecting with his own eyes the operation of the mechanism."

Dr. Schott and Robert Linton

Robert Linton of Los Angeles, who was associated with the American Window Glass Company during the early part of the present century, has written: "When I was at Charlottenburg, Dr. Otto N. Witt, in whose laboratory I was doing special work on glass, gave me a letter of introduction to Dr. Schott, and when I presented it at his works in Jena, he was more than kind. He showed me all through his plant and laboratories and spent practically the entire day with me personally. For him to show such a courtesy to me, who was only a student, was an experience that I shall always remember. It showed him to be a good deal the same sort as our own John A. Brashear, whose kindliness I shall always recall in a similar way."

These letters indicate Dr. Schott's interests and personality. With his passing on August 27, 1935, the world has lost the Dean of Glass Technologists, the outstanding individual in the field of chemical theory and technology as applied to glass. The man, Otto Schott, is no longer with us, but the fruits of his researches will serve as a monument as long as civilization lasts.

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METHODS FOR DETERMINING THE CHEMICAL DURABILITY OF SODA-LIME GLASSES*

By O. G. Burch

Abstract

The methods in general use for the determination of the chemical durability of soda-lime glasses are classified as to whether the sample tested is a finished glass article or a crushed glass sample of definite grain size. A method of the latter type is described which calls for treatment of a 10-gram sample of glass grains of specified mesh size with a definite quantity of $N/50$ sulfuric acid for a specified time at a definite temperature with subsequent determination of the alkali leached from the sample. A study of the results obtained, using both types of methods, is presented.

I. Introduction

The methods in general use for determining the chemical durability of soda-lime glasses may be grouped in four classes: (1) determination of the alkali extracted by an aqueous solution from a definite surface area of the finished glass article, (2) determination of the total material dissolved from a definite surface area of the finished article by solutions of water, acids, and bases, (3) a measure of the alkali extracted from definite weights of crushed glass of specified grain size by water or dilute acids, and (4) determination of the total material extracted from a definite amount of crushed glass of specified grain size by water, acids, and bases.

The writer hopes to prove that a test of the third type (3) is the most suitable for adoption as a standard test by the manufacturers and users of soda-lime glass articles.

II. Literature Review

In reviewing the literature on the subject, a number of tests are noted which might be classified under one of the four generalizations mentioned above. A few of these methods are cited in the chronological order in which they have been brought forth.

One of the earliest powder methods was that of Peddle,[1] whereby 5 g. of powdered glass, which would pass through a 160-mesh screen, were treated with distilled water for a period of one hour at 80°C. The solution was filtered and the undissolved material was determined by drying, the filtrate being titrated for alkali leached out. There are several factors about this test which make accurate conclusions difficult. Specifying grain size as finer than 160-mesh allows too great a variation in the surface area exposed to get reproducible results. The time of one hour is too short. Weighing the glass after extraction is inaccurate because of the different degrees of hydration which different glasses may undergo.

In 1922, Turner[2] published a review and criticism of the different types of durability tests then in use. Regarding loss in weight, alkali dissolved, etc., he stated that (1) loss-in-weight methods are inaccurate owing to hydration of the glass; (2) the alkali extracted by water is inaccurate owing to the difference in free and total alkali dissolved; and (3) determination of the extracted material is the best method, but the time element is too great.

* Presented at the Glass Division Summer Meeting, September, 1934. Received June 7, 1936.

[1] J. C. Peddle, "Development of Various Types of Glass: I, Interaction of Silica with the Oxides of Sodium and Potassium," *Jour. Soc. Glass Tech.*, **4**, 14 (1920).

[2] W. E. S. Turner, "Critical Examination of Methods Commonly Used in Determining Durability of Glass," *ibid.*, **6**, 30–45 (1922).

Concerning the form of the glass tested, he made the following statements: (1) it is nearly impossible to secure glass vessels of the same size and shape; the action of the vapor given off by the contained liquid also varies from that of the liquid for different shapes of containers; (2) autoclave tests can not be accepted as criteria of durability because some glasses exceptionally durable to hot water are inferior in the autoclave tests and *vice versa;* (3) samples of plates for immersion are difficult to prepare and a surface chilled by metal differs from an air-chilled surface; and (4) in powdered glass the surface differences due to cords, etc., are eliminated; the length of time necessary to get sufficient attack even on good glasses is greatly reduced over plane surface methods.

Dimbleby and Turner[3] used a powder method on grains of glass, lying between 20- and 30-mesh screens, carefully washed with alcohol to a constant weight. They subjected 10-g. samples of the glass to treatment at the boiling temperature for one-hour periods with water, acid, and alkali, measuring the loss in weight in each instance and titrating the alkali leached from the glass by water. They claimed the advantages for their method to be (*a*) a larger exposed surface over the use of glass disks, and (*b*) a more average condition of the glass.

Fischer and Tepohl[4] used a sample of 1 cc. of glass of grain size 0.15 to 0.30 mm.; this was washed with water to free from dust, treated with 50 cc. of H_2O for a period of 3 hours at 80°C, and 25 cc. of the filtrate was titrated with $N/100$ acid. The durability was expressed as volume of acid required.

Enss[5] used grains of glass 0.5 to 1.00 mm. in diameter and subjected an 18-g. sample of glass to treatment with 100 cc. of water for 7 hours at 100°C. The liquid was filtered off, evaporated to dryness, and the residue was analyzed. He found that treatment for 7 hours at 95°C gave 35% less attack than 7 hours at 100°C and that a $3^1/_2$-hour treatment at 100°C gave 20% less attack than 7 hours at the same temperature. He also claimed that the degree of annealing of the glass had no effect on results obtained by a powder method but did affect results obtained on a finished bottle.

At a joint meeting of the German and English Glass Societies in 1928, a compromise method,[6] calling for the use of 10 g. of crushed glass of 0.3- to 0.49-mm. size and treatment for 5 hours with water at 100°C with subsequent determination of the dissolved material, was proposed.

Fischer and Tepohl[7] tried this method, evaporating 75 cc. of the filtrate to dryness to obtain the extracted material, and found results consistent with those they obtained in their earlier method.

Botvinken and Tanchilevitch[8] used samples of glass of definite grain size and treated them with solutions of 0.01 N to 10.0 N alkalis and acids at definite temperatures for specified periods of time. They found that (H^+) had very little effect on the degree of attack but that (OH^-) materially affected the amount of corrosion.

Möller and Zschimmer[9] used a surface method for determining alkali dissolved. They had the glass formed as rods, 1 mm. in diameter and 125 mm. in length, and suspended these in water for 3 hours at 98°C, having sufficient rods that 1 cc. of water was present for each square centimeter of glass surface exposed. The alkali dissolved was then titrated with $N/100$ HCl. This method would probably give consistent results but the necessity of drawing the glass into rods makes it somewhat laborious.

Schmid[10] studied the durability of glass in water as a function of time and temperature by a conductivity method. The glass was made in the form of cylindrical containers of definite shape and volume. The containers were then filled with water of previously determined conductivity and maintained at constant temperature for definite periods of time, the conductivity being measured at desired intervals.

Some results obtained on a glass of the composition below follows:

TABLE I

			Conductivity = $K \times 10^{-6}$			
SiO_2	62.2	Time	$t=$	$t=$	$t=$	$t=$
R_2O_3	11.0	(hr.)	25°	50°	75°	90°
CaO	13.3	0	1.62	1.62	1.62	1.62
Na_2O	9.8	3	1.72	1.80	2.14	2.35
K_2O	3.6	6	1.80	1.92	2.51	2.65

In 1930 Rexer[11] made a criticism of durability methods then in use and expressed a preference for powder methods. Concerning surface methods in general he stated that (1) with an increasing ratio of volume to surface area, good glasses suffer less attack, poor glasses a greater attack; (2) leer gases influence the quantity and nature of material extracted; and (3) the manner of blowing of containers has an influence on the surface durability.

Flint and Lyle[12] offered a test in 1933, whereby bottles were filled with distilled water and maintained in an autoclave for 6 hours under a pressure of 35 lb. per sq. in., at the end of which period the alkali leached from the surface was determined by titration with a standard acid solution.

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[3] V. Dimbleby and W. E. S. Turner, "Relationship between Chemical Composition and Resistance of Glasses to the Action of Chemical Reagents: Part I," *Jour. Soc. Glass Tech.*, **10**, 304–58 (1926).

[4] E. Fischer and W. Tepohl, "Determination of the Soluble Alkali in Ground Glass," *Glastech. Ber.*, **4** [4] 137–42 (1926); *Ceram. Abs.*, **6** [7] 269 (1927).

[5] J. Enss, "Relationship of the Relative Water Stability of Glasses to Chemical Composition," *Glastech. Ber.*, **5** [10] 449–76 (1928); *Ceram. Abs.*, **7** [10] 749 (1928).

[6] "Proposed Standards for Measuring the Durability of Glass," *Jour. Soc. Glass Tech.*, **12**, 87 (1928).

[7] E. Fischer and W. Tepohl, "Solubility of Glasses in Water," *Glastech. Ber.*, **6** [9] 532–39 (1928); *Ceram. Abs.*, **8** [9] 641 (1929).

[8] O. Botvinken and A. Tanchilevitch, "Dependence of Alkaline and Acid Condition of Glass on Hydrogen-Ion Concentrations," *Z. anorg. allgem. Chem.*, **168**, 356–60 (1928); *Ceram. Abs.*, **8** [9] 647 (1929).

[9] W. Möller and E. Zschimmer, "Hot Alkaline Solubility of the Fire-Polished Sodium-Lime-Silica Glasses as Function of the Chemical Composition," *Sprechsaal*, **62** [7] 115–16 (1929); *Ceram. Abs.*, **8** [9] 535 (1929).

[10] C. Schmid, "Effect of Time and Temperature on Solubility of Bottle Glass in Water," *Sprechsaal*, **63**, 759 (1930); *Ceram. Abs.*, **10** [1] 25 (1931).

[11] E. Rexer, "Critical Investigation of Methods for the Determination of Glass Durability," *Keram. Rundschau*, **38**, 387 (1930); *Ceram. Abs.*, **10** [7] 481 (1931).

[12] F. C. Flint and A. K. Lyle, "Test for Chemical Resistance of Glass Containers," *Bull. Amer. Ceram. Soc.*, **12** [10] 296–99 (1933).

The writer presented a test a few months ago which has been in use for several years with considerable success. The glass is crushed to pass a 40-mesh and remain on a 50-mesh screen. It is then washed free from dust by rinsing in alcohol and dried, and a 10-g. sample accurately weighed out into a resistant glass flask; 50 cc. of $N/50$ H_2SO_4 are run into the flask, which is loosely stoppered, and maintained on a water bath for a period of four hours at a temperature of 192°F. The flask is quickly cooled in running water, the excess acid is titrated with standard alkali solution to a phenol red end-point, and the alkali leached from the glass is computed in terms of percentage of Na_2CO_3.

The writer believes that this test gives reproducible results which may be interpreted in terms of the weather resistance of the glass. Although it is impossible to devise any durability test which will reproduce weathering conditions, any test that will afford a reliable measure of the ease with which alkali is leached from the surface of the glass will indicate the weather resistance of that glass.

(1) Effect of Soluble Alkali

The writer believes that soluble alkali is a more reliable measure than total extracted material for the following reasons:

(1) Becker and Kraft[13] determined the durabilities of the following glasses by two methods, (*a*) the standard method adopted in Germany in 1928, whereby the material extracted from 10 g. of glass, 0.3- to 0.49-mm. grain size, by

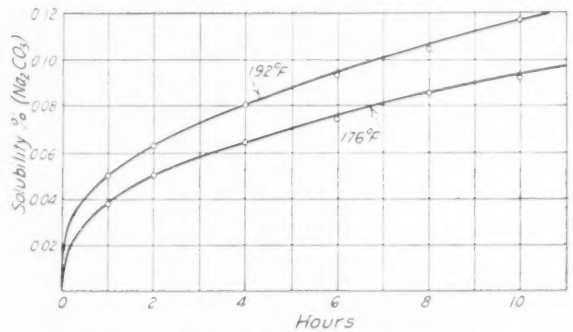

FIG. 1.—Effect of time of test on solubility.

100 cc. of water at 100°C in 5 hours is determined and expressed in milligrams and (*b*) 2 g. of glass grains, 12- to 20-mesh, are immersed in 50 cc. H_2O for 1 hour at 100°C and the alkali extracted is determined by titration with standard acid.

Thus it would appear that, from the total amount of extracted material, glass No. 1 is more resistant to weathering, while on the basis of soluble alkali No. 2 is the more resistant. That the latter is the case, we know from actual experience with glasses of practically the same compositions.

(2) Enss[5] replaced SiO_2 by the basic oxides CaO, MgO, BaO, Al_2O_3, and B_2O_3 in a parent glass of 82% SiO_2 and 18% Na_2O and concluded that, from the total material extracted, for 5% addition of the oxides the order in which the oxides increased the durability of the glasses was B_2O_3, Al_2O_3, CaO, MgO, and BaO, while for 10% addition the order was Al_2O_3, CaO, B_2O_3, MgO, and BaO. We know, however, from our experimental work that the alkali leached from glasses does not follow in that order of basic oxides and that from changes we have made in glass compositions the weather resistance of glass does not improve in that order.

TABLE II

	No. 1	No. 2
SiO_2	74.81	74.81
R_2O_3	0.74	0.56
CaO	7.47	5.45
MgO		2.48
Na_2O	16.64	15.92
K_2O	0.22	0.20
Extracted mg.	41	57
$N/100$ HCl (cc.) to neutralize alkali	3.61	3.15

(3) Several years ago, while experimenting with durability tests and glass compositions, we made the following tests: Two glasses, which we were using on two furnaces in the same plant, having the same alkali content but different dibasic oxide contents, were selected for treatment. Ten-gram samples of 40- to 50-mesh glass, previously washed free from adhering dust particles, were placed in 100 cc. of distilled water in Pyrex-brand flasks and maintained at 100°C for a period of 5 hours. Reflux condensers were attached to the flasks to prevent evaporation of the liquid. At the end of 5 hours the flasks were quickly cooled and 75 cc. of liquid filtered; 50 cc. of each sample were evaporated to dryness, ignited, and weighed, and the total extracted material was determined. The remaining 25 cc. of liquid was titrated with standard acid to determine the total alkali leached from the glass. Durabilities of the two glasses were also run by the method we ordinarily employ. The results are shown in Table III.

TABLE III

	Glass No. 1	Glass No. 2
Material extracted (%)	0.382	0.436
Na_2O dissolved (%)	.086	.073
Na_2CO_3 (standard) (%)	.097	.079

We know, however, both from artificial and actual weathering tests which we conducted in tropical climates that glass No. 2 is the more resistant to weathering. The soluble alkali proves this statement and the total extracted material does not.

III. Relative Merits of Powder and Surface Methods of Measuring Durability

It is claimed by proponents of a durability test made on the actual surface of the finished article that any test made on a powdered sample does not give a measure of the actual durability of the surface of the finished article, which is the factor

[13] C. A. Becker and C. Kraft, "Composition and Hydrolytic Stability of Molded Glass," *Sprechsaal*, **16**, 261 (1929); *Ceram. Abs.*, **9** [6] 417 (1930).

sought. Whether or not this theory is true, the results obtained with the powder method given above have exactly parallelled the weather resistance of our glass with no discrepancies.

If new bottles of the same size and shape are used and if the surfaces have not been subjected to an abnormal treatment such as exposure to acid gases, the results obtained by powder and surface methods show good agreement on the same glass. The glasses of the following compositions, all of which were new 4-ounce prescription bottles of the same size and shape, were tested for soluble alkali by three methods as follows:

TABLE IV

Glass No.	1	2	3	4	5	6	7	8
SiO_2	74.60	74.60	74.24	74.66	73.62	76.26	74.34	73.66
R_2O_3	0.80	0.45	0.76	0.45	0.70	1.00	1.44	1.08
CaO	3.69	4.64	4.64	6.20	4.72	4.38	4.64	5.36
MgO	1.94	2.99	3.08	2.26	3.23	2.79	3.10	3.74
BaO		0.70	0.39		0.76			0.49
B_2O_3					0.67		0.32	0.76
Na_2O	18.93	16.35	16.46	16.21	16.01	15.34	15.80	14.62
Total	99.96	99.73	99.57	99.78	99.71	99.77	99.64	99.71
Durability								
No. 1 (% Na_2CO_3)	0.353	0.151	0.136	0.126	0.112	0.093	0.093	0.056
No. 2 (g. Na_2CO_3)	.0313	.0187	.0156	.0150	.0124	.0103	.0097	.0057
No. 3 (g. Na_2CO_3)	.0070	.0031	.0026	.0031	.0024	.0021	.0021	.0014

(1) The powder method with 50 cc. $N/50$ H_2SO_4, as described above.

(2) The method proposed by Flint and Lyle,[12] somewhat modified, whereby the bottles were rinsed and filled $^3/_4$ full with distilled water, stoppered with cotton, placed in an autoclave, and maintained therein for a period of 5 hours under 30 lb. steam pressure (274°F); the bottles and contents were cooled and titrated to a phenolphthalein end-point with $N/20$ HCl.

(3) A somewhat modified version of a test recommended as a standard test and the specifications for the chemical durability of 4-ounce flat medicine bottles[14] adopted in England in 1931. The bottles were rinsed several times with tap water, 3 times with $N/10$ acetic acid, 4 times with tap water, and once with hot distilled water. They were filled with boiling distilled water, stoppered with cotton, placed in a steam atmosphere in an autoclave, and maintained therein for 5 hours at a temperature of 100°C. The contents were transferred to an Erlenmeyer flask, and 25 cc. of $N/50$ H_2SO_4 was added to each sample. The solutions were titrated to a phenol red end-point with $N/50$ NaOH. The analyses and durability results by each of these methods are as shown in Table IV.

Method No. 3 seems to show several discrepancies, but the amount of alkali dissolved in most instances was so small that good accuracy can not be expected.

It is to be noted that, for 4-ounce bottles of the particular shape used, the amount of alkali dissolved from the bottle in 5 hours at a temperature of 270°F is approximately the same as that dissolved from a 10-g. sample of 40- to 50-mesh glass in 4 hours at 192°F. On the other hand, the amount of alkali dissolved from the surfaces of the bottles in 5 hours at 212°F is approximately only 20% of the amount dissolved in 4 hours at 192°F from 10 g. of the powdered sample.

IV. Effect of Age of Bottle on the Amount of Alkali Dissolved from the Surface of a Bottle

To show what effect the age of storage and surface treatment might have upon the soluble alkali from the surface of a bottle, tests were run on two 7-ounce flasks of the same glass, from the same furnace, and made at the same time. One had been stored in Porto Rico for two months and was not noticeably weathered and the other, stored in Porto Rico for 20 months, was considerably weathered. They were rinsed three times with warm tap water and once with distilled water, partially filled with 150 cc. of $N/150$ H_2SO_4, stoppered with cotton, and placed in a water bath at 192°F for 24 hours. The contents of the flasks were transferred to beakers, cooled, and titrated with $N/50$ NaOH to a phenol red end-point.

The following results were noted: No. 1 (2

[14] "Standard Test and Specification for the Chemical Durability of 4-Ounce Flat Medicine Bottles," *Jour. Soc. Glass Tech.*, **15P,** 52 (1931).

months in Porto Rico) 0.0019 g. Na_2O and No. 2 (20 months in Porto Rico) 0.0037 g. Na_2O.

The bottle which had been exposed to tropical climate for 20 months showed twice as much soluble alkali as the one stored there for 2 months. With the powder method, similar samples of the two bottles showed 0.080% Na_2CO_3.

Twelve-ounce flasks of a different glass composition were washed similarly, partially filled with 300 cc. $N/300$ H_2SO_4, and maintained at 192°F for 18 hours, and the soluble alkali was similarly determined. The results of the test on these bottles, all of which were made at the same time, were as follows: No. 1 (stored in Porto Rico 2 months) 0.0033 g. Na_2O and No. 2 (stored in Porto Rico 20 months) 0.0073 g. Na_2O.

Here again the influence of the age of the bottle is to be noticed.

V. Influence of Leer Atmosphere on Amount of Alkali Dissolved from a Glass Surface

A simple test showing the influence of leer atmosphere was conducted as follows: 16-oz. round bottles made on the same machine were annealed in two types of leers, electric and gas-fired. The bottles were rinsed with tap water and distilled water, and each was partially filled with 400 cc. of distilled water and 50 cc. of $N/50$ H_2SO_4. They were maintained in a water bath for 42 hours at 192°F; the contents were transferred to Pyrex-brand flasks and were cooled and titrated with $N/50$ NaOH to a phenol red end-point. The results were as follows:

Electric leer	Gas-fired leer
0.0060 g. Na_2O	0.0057 g. Na_2O
.0061 g. Na_2O	.0057 g. Na_2O

This small difference is easily detectable and shows that leer atmosphere has an effect on the durability of the glass.

In view of the evidence presented, we believe that the chief difficulties and handicaps presented by a surface method as contrasted to a powder method are as follows:

(1) It is practically impossible to secure bottles of the same size and shape from all furnaces, and unless this is done the results by a surface method on bottles are worthless.

(2) The amount of alkali leached from a fairly large bottle at a definite temperature in a definite time is considerably less than that leached from a 10-g. powdered sample under the same conditions, thus decreasing the comparative accuracy of the results.

(3) If it is desired to use disks, slabs, or rods in a surface method, unless such samples are made without contact with a metal surface, the durability of the metal-chilled surface will vary from that of the air-chilled surface.

(4) Using a method depending upon the alkali leached from the surface of a bottle, not only the age of the bottle, but also the atmosphere of the leer in which it was annealed must be taken into consideration and it is almost impossible to compensate for either of these factors.

VI. Influence of Certain Factors Involved in Powder-Test Methods

(1) Dilute Acid vs. Water

Dilute acid rather than water is used in this test because more consistent results are obtained, especially on glasses of low durability where the sodium silicate formed by water attack makes it difficult to get correct results. Numerous investigators have found that in using water there is no marked relationship between the weight of sample used and the results obtained, *i.e.*, the results vary with the weight of sample and volume of liquid employed. This is readily understood since, after the first alkali is leached from the glass, the attacking liquid is constantly becoming more alkaline in nature. This effect will be discussed later. A few durability factors, obtained by using both $N/50$ acid and water on several glasses at a temperature of 192°F, are given in Table V.

TABLE V

Glass No.	% Na_2CO_3 ($N/50$ acid)	% Na_2CO_3 (H_2O)
1	0.080	0.080
	.080	.077
2	.085	.084
	.086	.089
3	.086	.082
4	.071	.069
5	.068	.065
6	.076	.079
	.078	.079
7	.106	.104
8	.144	.121
	.148	.125

It is to be noticed that for glasses of average durability the results obtained with dilute acid and with water are fairly concordant, but for less durable glass such as No. 8 there is considerable divergence.

(2) Effect of Time and Temperature on the Amount of Alkali Dissolved

We have done a small amount of work on the effect of time and temperature on durability tests. Running tests at the temperatures of 176° and 192°F on a glass of the composition quoted we get the following results:

SiO_2	74.20
R_2O_3	0.76
CaO	5.41
MgO	3.78
BaO	0.47
Na_2O	15.37

TABLE VI

Time (hr.)	Na_2CO_3(%) (176°)	Na_2CO_3(%) (192°)
0.25		0.032
0.5		.042
0.75		.047
1.0	0.038	.050
2.0	.050	.063
4.0	.064	.080
6.0	.074	.093
8.0	.085	.105
10.0	.092	.117

Enss[5] found that there was about 35% less material extracted by water at 95° than at 100°C in the same length of time and that in $3^1/_2$ hours at 100° the material extracted is 20% less than in 7 hours at 100°.

Gehlhoff and Schmidt[15] stated that with water at 100°C approximately 70% of the material extracted in 10 hours is extracted in 5 hours. By plotting our results, we find that a difference of 9°C in temperature makes about 20% less alkali extracted throughout; at both 176° and 192° the amount of alkali extracted in 5 hours is approximately 75% of that extracted in 10 hours, while in 4 hours about 70% of that extracted in 10 hours is accomplished.

We also find that Keppeler's[16] formula,

$$C = \frac{X_2^2 - X_1^2}{t_2 - t_1}$$

holds true at both 176° and 192°, although the value of C is naturally different for the two temperatures, as the time increases from 1 to 10 hours.

Where C = a constant for the glass.
t_2, t_1 = time in hr., respectively.
X_2, X_1 = amounts of alkali dissolved at t_2 and t_1.

(3) Effect of Volume and Concentration of Solution

To determine the possible effects of acid concentration and volume upon the amount of alkali leached from glass, the following results were obtained from bottles of the same composition; 10-g. samples were used in each instance.

TABLE VII

Volume (cc.)	Normality	Na_2CO_3 (%)
50	$N/50$	0.078
		.077
100	$N/50$	.074
		.076
25	$N/50$	.074
		.076
50	$N/100$	.077
50	$N/20$	.074

It is obvious from these results that neither the strength nor volume of sulfuric acid used has any appreciable effect on the result obtained. It is probable though that greater volumes would give lesser results in the same period of time because of the greater lag in time necessary for the acid to reach the temperature of the water bath. We believe that $N/50$ acid gives more reproducible results than stronger acids because a drop or two difference in check samples of the stronger acids causes a more appreciable discrepancy in the results. Fifty cubic centimeters is a convenient volume to use and we see no reason for changing this volume.

It is evident that the action of dilute sulfuric acid is similar to that of distilled water, the only part played by the acid being the neutralization of alkali dissolved from the glass, thus preventing attack by an increasingly alkaline solution as is the case with distilled water.

(4) Effect of Weight of Sample on Results Obtained

Turner[2] and Rexer,[11] in their criticisms on powder methods measuring the total material extracted by water, state that there is no absolute relationship existing between the weight of sample used and the amount of attack occurring. The following results on the same glass, using weights from 1 to 20 g., show that in the method we are using for soluble alkali there is a relationship between weight of sample and the results obtained, *i.e.*, 50 cc. $N/50$ H_2SO_4 used 4 hours at 192°F.

It is evident that any weight of sample may be used with good agreement of results. Obviously the larger the sample the greater the accuracy. Considering the ease of preparation and simplicity of calculation, however, 10 g. is believed to be the best weight. The above results serve further to prove that the action of dilute sulfuric

[15] G. Gehlhoff and R. Schmidt, "Storage and Packing of Glassware," *Sprechsaal*, **60**, 337 (1927); *Ceram. Abs.*, **6** [12] 570 (1927).

[16] G. Keppeler and M. Thomas-Welzow, "Time Dependence of Water Attack in Glass," *Glastech. Ber.*, **11** [6] 205–208 (1933); *Ceram. Abs.*, **13** [4] 85 (1934).

acid is similar to that one could expect if it were possible to have continued action of distilled water without the accompanying gradual increase in alkaline attack associated with the action of distilled water on glass. In other words, with an increasing amount of sample one should expect an increasingly alkaline attack with distilled water.

TABLE VIII

Sample (weight)	Na_2CO_3 (%)
1.0	0.074
2.5	.076
5.0	.076
	.076
10.0	.076
	.076
15.0	.078
	.078
20.0	.076
	.075

(5) Effect of Grain Size of Glass upon Amount of Alkali Leached from Glass by a Dilute Acid Solution

The question as to the proper grain size of material to use naturally rises. Concerning this there are several governing factors. (1) If the grain size is too large, the amount of soluble alkali leached from a 10-g. sample will be small, thus decreasing one of the real merits of a powder method, *i.e.*, the ability to secure a relatively large attack in a relatively short time. (2) If the grain size is too small, the time necessary for preparation of the sample will be considerably increased. (3) The limits of grain size should be close enough to avoid too great a variation in the size of grains, thus increasing the consistency of results, and yet not too close for convenient rapid preparation of the sample. The following results show the number of crushings and screenings necessary with a 100-g. original specimen of glass to secure a 10-g. sample, with the amount of alkali dissolved for each grain size. All of the tests were conducted on 10-g. samples, using 50 cc. of $N/50$ H_2SO_4 for each sample and heating 4 hours at 192°F.

TABLE IX

Mesh No.	Grain size (mm.)	No. crushings and screenings	Na_2CO_3 (%)
30–20	0.589–0.833	1	0.049
			.046
40–30	.417– .589	1	.057
			.059
50–40	.295– .417	2	.077
			.076
60–50	.246– .295	5	.096
			.096

The 50- to 60-mesh size is eliminated as the time for preparation of the sample is too great. The 20- to 30-mesh size is not to be desired because the amount of alkali dissolved would appear to be quite small on extremely good glasses, thus decreasing the accuracy of the method. From the standpoint of ease of preparation, the 30- to 40-mesh size is apparently better than 40- to 50-mesh as only one crushing and screening is necessary, using an initial amount of 100 g. of glass to secure a sufficient quantity for a 10-g. sample. On the other hand, it is believed that the narrower limits of grain size of the 40- to 50-mesh grains justify the small amount of extra work in preparing the sample, making for more accurate results. Using 40- to 50-mesh grains, we have found the durability factors of the common bottle glasses in this country to vary from 0.055 to 0.350% Na_2CO_3. Thus even with the best type of glass there seems to be sufficient alkali dissolved from 10 g. of 40- to 50-mesh glass to obtain a good degree of accuracy in the results.

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BONDING STRENGTH OF COLD-SETTING REFRACTORY CEMENTS*

By R. A. Heindl and W. L. Pendergast

Abstract

The rate of absorption and transverse strength of five brands of fireclay brick and the water content, particle size, pyrometric cone equivalent, drying shrinkage, and transverse strength of four cold-setting fireclay cements were studied. Each of the cements, representing different types, are used with each of the five brands of brick, also representing different types, in tests of the unfired bonding strength. The results indicate that the bonding strength of the cement is greatly influenced by the rate of absorption and transverse strength of the brick with which it is used.

I. Introduction

A cold-setting or air-setting refractory cement is a bonding mortar suitable for use at both low and high temperatures. The increasing number of brands of such cements and production statistics indicate a real demand for this comparatively recent addition to the refractories group. Refractory cements of widely varying properties have been placed on the market, and it is to be expected that certain of these materials will prove to be more suitable in one type of service than in another, while others may prove satisfactory in nearly all types of service. It is, therefore, essential to evaluate the properties of these cements to aid in their selection for specific services. Among the tests which may be readily made and which undoubtedly will be included as a requirement in specifications for such cements is a test to indicate the bonding strength. A definite relation between the rate of absorption of building brick and strength of bond has been pointed out by Palmer and Parsons.[1] It was, therefore, considered advisable to make a series of tests to determine whether the same relation applies in the case of firebrick and fireclay cements. If the relation applies, it is necessary to recognize it in the formulation of a specification covering cold-setting refractory mortars.

II. Selection and Testing of Materials

Five conveniently available brands of brick, the appearance of which indicated the desired range in rate of water absorption, were chosen for this study.

Four brands of cold-setting refractory cements marketed in the wet condition were chosen so as to be fairly representative of the various types of commercial fireclay mortars. The cements included may be described as (1) very sandy, somewhat short for easy troweling, (2) very fatty, somewhat thick for troweling, (3) medium fatty, somewhat thin for troweling, and (4) medium sandy and of good troweling consistency. These were used without the addition of water to avoid changing their consistency. Some cements show a tendency for the liquid to segregate at the top of the container, the solid portion of the cement becoming rather hard and difficult to remove. When a cement in this condition is placed in a kneading or mixing machine, however, the original consistency is again in evidence.

(1) Fireclay Brick

(a) Absorption Rates

The percentage absorption at the end of 1-, 3-, and 10-minute periods was taken as an index of the rate of absorption and was measured for each brand as follows: After drying at approximately 90°C for not less than 24 hours and cooling, one end of each brick was submerged in water to a constant depth of $^1/_8$ inch. At the end of the specified time intervals, the change in weight was noted and the percentage absorption was computed. The total absorption was determined by boiling the specimens for 5 hours and allowing them to cool overnight in the water. The average percentages of absorption for the different time intervals as well as the total absorptions are given in Table I.

(b) Transverse Strength

The transverse strength of not less than five brick of each brand was determined, using a 7-inch span. The method of test and manner of

* Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

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[1] L. A. Palmer and D. E. Parsons, "A Study of the Properties of Mortars and Bricks and Their Relation to Bond," *Bur. Stand. Jour. Research*, **12** [5] 609–44 (1934); R.P. 683.

TABLE I

ABSORPTION AND STRENGTH OF BRICK

Brand* of brick and texture	Water absorption at end of			Total absorption at end of 5 hr. boiling (%)	Modulus of rupture (lb./in.²)
	1 min. (%)	3 min. (%)	10 min. (%)		
K (very fine, dense)	0	0	0	1.5	2665
P (moderately coarse)	1.5	2.5	4.3	8.6	745
D (fine, open)	3.2	5.0	8.0	12.7	440
S (very coarse)	3.2	4.6	7.5	13.4	470
L (coarse)	3.8	6.0	9.2	14.6	400

* Texture based on a visual examination only.

computing the modulus of rupture are described in the standard method of testing brick, A.S.T.M. Designation C 67–31.[2] The values are given in Table I.

(2) Refractory Cements

(a) Water Content

The water content of the cement was obtained by determining the loss after drying to constant weight at 110°C. A sample of approximately 200 grams was used for each test. The results, based on the dry weight of the material, are given in Table II.

(b) Sieve Analysis

The sieve analysis was made of a 200-gram sample from each of the cements, using U. S. standard sieves Nos. 20, 35, 60, and 100. The wet method of analysis was used and the sieving of the dried residue was accomplished with a machine.[3] The results are given in Table II.

(c) Pyrometric Cone Equivalents

The pyrometric cone equivalents were determined according to the A.S.T.M. standard method, Designation C 24–33.[4] The cements were tested without a preliminary calcining treatment and also after such a treatment at approximately 1200°C, and the results are given in Table II.

[2] American Society for Testing Materials Book of Standards for 1933, Part II, p. 128.

[3] The manner of conducting the test was in general similar to method C 92–34T, p. 28, American Society for Testing Materials, Standards on Refractory Materials (special publication, 1935).

[4] American Society for Testing Materials Book of Standards for 1933, Part II, p. 184.

TABLE II

SOME PROPERTIES OF COLD-SETTING REFRACTORY CEMENTS

Brand No.	Type	Consistency	Water[1] content (%)	Linear drying shrinkage (%)	Pyrometric cone equivalent		Sieve Analysis,[1] Total retained on			Modulus of rupture (lb./in.²)	Transverse strength of bonded specimens made with brick[3] of different strengths and rates of absorption		Type of failure[4]
					Uncalcined (cone)	Calcined (cone)	No. 35 (%)	No. 60 (%)	No. 100 (%)		Brand of brick	(lb./in.²)	
1	Very sandy	Short	22.5	5	29–30	29–30	0.75	15.3	17.3	900	K	325	*M* and *J*
											P	70	*M* and *J*
											D	35	*J*
											S	40	*J*
											L	40	*M* and *J*
2	Very fatty	Thick	25.8	8	27	26	.04	3.9	10.2	2335	K	65	*J*
											P	120	*J*
											D	85	*J*
											S	90	*J*
											L	55	*J*
3	Medium fatty	Thin	24.7	6	26	27	0	0	0	3415	K	475	*M*, *B*, and *J*
											P	275	*M*, *B*, and *J*
											D	245	*M* and *B*
											S	125	*M*, *B*, and *J*
											L	130	*M*, *B*, and *J*
4	Medium sandy	Good working	25.4	2	?[2]	31–32	2.57	8.4	12.2	3325	K	630	*M*
											P	405	*B*
											D	415	*B*
											S	245	*B*
											L	190	*B*

[1] Based on dry weight.
[2] Unable to obtain satisfactory end-point.
[3] See Table I for strengths and rates of absorption.
[4] *J* indicates failure occurred between mortar and brick; *M*, failure within the mortar; *B*, failure due to rupture of brick.

There is some difference of opinion regarding the advisability of heat treatment before testing for pyrometric cone equivalent; therefore, it was considered desirable to include the results obtained under the two conditions.

(d) Strength and Shrinkage

The modulus of rupture was determined on bars, 6 by 1 by $^1/_4$ inch, over a 5-inch span. To prevent too rapid drying and also to insure uniform treatment, the following drying schedule was followed for each cement: 48 hours at approximately 60 to 65% humidity[5] and at 20 to 22°C, 18 hours at ordinary room temperature and humidity, and 27 hours at approximately 105°C. The bars were turned over a number of times during the drying treatment to prevent warpage. The results of the tests, given in Table II, represent the average values obtained on ten specimens.

The linear drying shrinkage was determined on the bars used for the transverse strength tests. These results are given also in Table II.

III. Nature of Bonding Test and Results

The standard-size (9-inch) brick, used in the test for the determination of strength of bond with the various cements, were cut by means of an abrasive wheel into two equal parts parallel to the $2^1/_2$- by $4^1/_2$-inch faces. They were then placed overnight in a drier maintained at approximately 90°C. An ordinary laboratory screw-press was slightly changed to accommodate a 9-inch brick on end. Aligning guides and clamps were attached to the frame of the press to prevent slipping of the two halves of the brick when they were forced together with the mortar between them. The operation of bonding was as follows: After clamping the two halves of the brick in place with the cut faces at the far ends,[6] two spacers, $^1/_2$ inch wide and $^1/_{16}$ inch thick, were placed on the lower half of the brick and the upper half was then brought in contact. The reading indicated on a scale was noted, the upper section of brick was raised about $^3/_4$ inch, the spacers were removed, approximately 100 grams of mortar were placed between the half-brick, and the upper portion was again lowered until the scale reading corresponded to that first noted. The excess material amounting to about 50 grams was removed and the specimens were released from the clamps. The entire operation consumed approximately $^3/_4$ minute. They were then removed to the humidity room, using care to avoid jarring, and stored on end for drying. The drying procedure for this series of tests consisted of keeping the specimens for 48 hours at 60 to 65% humidity and at a temperature of 20 to 22°C, and thereafter for 24 hours at approximately 90°C.

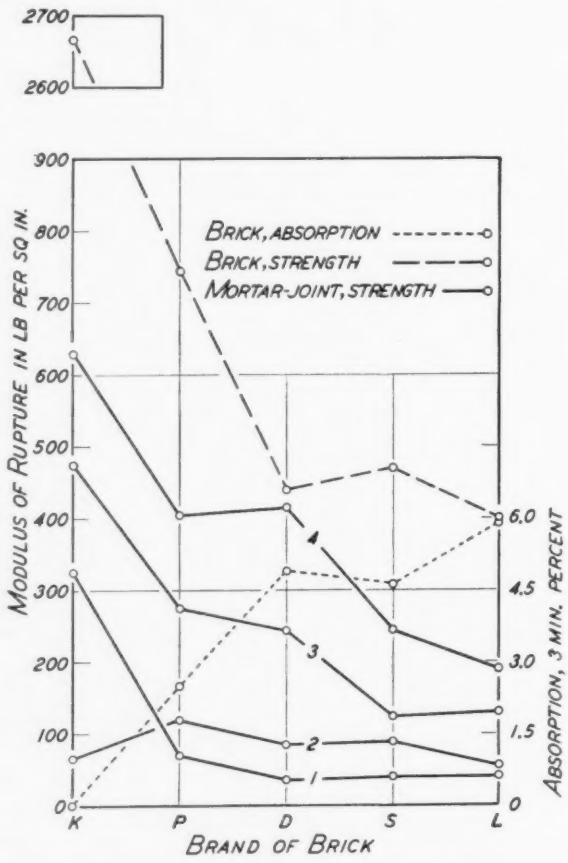

FIG. 1.—Showing that the strength of the bonded firebrick specimens was dependent on the type of brick, unless failure occurred solely in the joint, those with low rate of water absorption and high strength giving the strongest specimens.

The drying treatment was adopted after making a few tests with one brand of cement and one brand of brick. It was found that the strength of the joint increased quite rapidly up to about 96 hours in the humidity chamber with comparatively little change thereafter up to 168

[5] The humidity and temperature ranges are conveniently available at all times in one of the rooms at the Bureau, and use was made of those facilities for this study.

[6] The original surface of the brick was bonded rather than the cut surface to simulate practical conditions.

hours. The drying at 90°C, however, increased the strength quite appreciably.

The modulus of rupture of the bonded specimens was determined, using a 7-inch span, and the results are given in Table II. The type of failure is also indicated in this table. Three general modes of failure of the joint noted were,

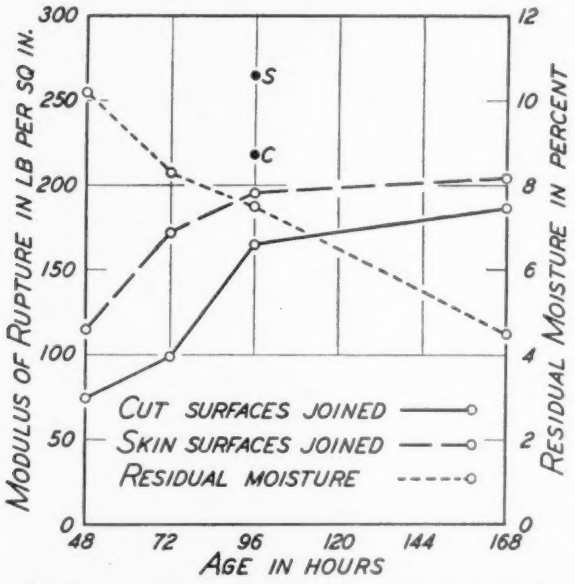

Fig. 2.—Showing the bonded strength of specimens after different aging periods when the skin or outside surfaces of brick are joined, in contrast to the strength when the surfaces produced by cutting the brick are joined. The moisture remaining in the cement after the joint was ruptured is also shown, without differentiating the types of surface from which removed. The filled-in circles, designated *S* and *C* (skin and cut surfaces, respectively), represent the strength of the mortar joints after aging 72 hours in the humidity chamber and 24 hours at approximately 90°C. These values are the only ones obtained after drying at 90°C and might be considered the maximum strength of the joints.

(1) the brick failed rather than the cement, (2) the cement pulled away from the surface of the brick, and (3) the failure occurred within the cement.

The strength of the brick, the percentage water absorption at the end of 3 minutes, and the strength of the bonded specimens are shown in Fig. 1. The data indicate a decided relation between these properties, the brick with a low rate of water absorption and high strength giving the highest strength values. The bonded specimens made with cement No. 2 failed to show the same trend as the others. This was the only group of specimens which failed exclusively in the joint. Where the failure occurred in the brick (see No. 4, Table II) rather than in the cement or mortar joint, it may be noted that the apparent strength of the cemented brick is, in some cases, considerably below the strength given in Table I. This could be accounted for by the assumption that in such cases the central portion of the original brick is stronger than the portions near the rim. There is also the possibility that silicate of soda from the cement enters the pores of the brick and has a destructive influence during drying.

A comparison was made of the strength of cemented joints when the two cut surfaces were joined and when the two original outside or skin surfaces were joined. Brick *P*[7] was used in these tests, and the results after different drying periods are shown graphically in Fig. 2. Failure occurred in the mortar and joint, and the moisture retained in the cement which adhered to the brick after the test was determined. These results also are given in Fig. 2. They show that the water content continued to drop during the entire 168 hours at a fairly uniform rate, although not materially affecting the strength of the joint after a 96-hour curing.

IV. Summary and Conclusions

Four commercial brands of cold-setting refractory cements representing a wide range in type and consistency and marketed in the wet condition were studied. The water content of these cements ranged from 22.5 to 25.8%, the linear drying shrinkage from 2 to 8%, the material retained on a No. 60 U. S. standard sieve from 0 to 15.3%, the pyrometric cone equivalent from 27 to 31 or 32, and the transverse strength from 900 to 3415 pounds per square inch. Five brands of brick, used for determining the modulus of rupture of the cement-bonded specimens, ranged in transverse strength from 400 to 2665 pounds per square inch and in total absorption from 1.5 to 14.6%.

The results show that in general the modulus of rupture of the bonded specimens is influenced by the type of brick, those with a low rate of water absorption and a high transverse strength giving the strongest bonded specimens. Therefore, a specification containing a requirement for unfired bonding strength, as found in the tentative specification[8] adopted by the American Refractories Institute, should contain also a requirement for the type of brick used for the bonding test.

[7] The cement used is not included in the four referred to in Table II.

[8] S. M. Phelps, "A Specification and Test Methods for Cold-Set Cements," *Amer. Refrac. Inst. Tech. Bull.*, No. 60.

ACTIVITIES OF THE SOCIETY

APPRECIATION OF THE LOCAL COMMITTEE AT ANNUAL MEETING

It is to Mrs. Ellsworth P. Ogden, ably assisted by Mrs. Edward Orton, Jr., and the wives of other ceramists located in Columbus, that the ladies are indebted for the excellent and instructive entertainment. They made their plans in detail and efficiently.

To John L. Carruthers the delegates, who took advantage of the plant trips, are indebted for the careful planning and the efficient execution of the plans for these plant trips.

Arthur S. Watts arranged for general exhibits in the lobbies of the hotels and a sub-committee with Arthur E. Baggs, Mrs. Orton, and Carlton Atherton arranged quite an extensive exhibit in the Fine Arts Gallery. They also had the collaboration of the Huntington National Bank which, in its spacious building, had a beautiful, broadly-conceived exhibit. The Ohio Ceramic Industries Association, B. T. Bonnot, President, and Harry E. Nold, Secretary, provided prizes for the ladies, which constituted a very substantial exhibit. Altogether we had an exhibition of ceramic ware which did much to make the people in Columbus and its environs conscious that in America the highest grade ceramic ware of all sorts are being produced.

The Publicity Committee, Clyde E. Williams, Chairman, with Harold E. Simpson and F. B. Hobart, secured the coöperation of the Chamber of Commerce, the daily press, and the technical journals throughout the country in giving wide pre-meeting publicity to the Meeting. Judging from the reports from all over the country the work of this Publicity Committee was probably the most efficient which the Society has had in connection with any of its Meetings. This Committee worked diligently.

Under the general chairmanship of George A. Bole, representing the Central Ohio Section, all members of the Society located near Columbus collaborated in excellent fashion and had all detailed arrangements made long before the opening day of the meetings. To them, individually and collectively, I express appreciation for the diligent services rendered.

—Ross C. Purdy, *General Meeting Chairman*

WHY OUR ANNUAL MEETINGS WERE CONDUCTED SMOOTHLY

In Buffalo it was Grant S. Diamond and his committee and the students of the New York State College of Ceramics; in Columbus it was John D. Sullivan and his Meeting Service Committee, mainly C. A. Austin, together with employed students from the Ohio State University. No one noticed Mr. Sullivan as he cruised about the two hotels, seeing that everything was in readiness and the boys in their places to meet every meeting and luncheon demand. As with Mr. Diamond so it was with Mr. Sullivan. The work was quietly and efficiently done.

John D. Sullivan

Mr. Sullivan had a harder task in Columbus in that the meetings were held in two different hotels. A private wire was run between the two hotels and it was by this private telephone that information was obtained in each meeting room of the papers about to be presented in the others. It was over this telephone also that Mr. Sullivan kept in close touch with his little army of meeting attendants.

In answer to the oft-asked question of why the meetings ran so smoothly, the answer must be the very efficient management and careful attention to details on the part of John D. Sullivan.

It is with a sense of indebtedness and gratitude that, as General Meeting Chairman, I am able to show here the likeness of Mr. Sullivan and to give a brief account of his scholastic and technical experiences and achievements.

John D. Sullivan was born in Columbia Falls, Mont., February 4, 1900. In 1921 he received the degree of B.S.

in Chemistry from the University of Washington. A year later he took his M.S. degree in Chemistry and Metallurgy at the same University. He then did graduate work in physical chemistry at the University of California from 1923 to 1927. In 1927 he also took graduate work in mining administration at the University of Arizona.

Between 1922 and 1923 Mr. Sullivan was Analyst with the U. S. Bureau of Mines, Seattle, Wash. From 1923 to 1927 he was Physical Chemist with the Bureau of Mines, Berkeley, Calif. For the next four years he was Metallurgist with the Bureau of Mines, Tucson, Ariz. In 1931 he took his present position with Battelle Memorial Institute, Columbus, Ohio, as Chief Chemist.

Mr. Sullivan is a member of the American Ceramic Society, the American Institute of Mining & Metallurgical Engineers, the Electrochemical Society, and the Society of Glass Technology. He is Chairman of the A.S.T.M. Committee C-8 on Refractories, and a member of the Committee on Hydrometallurgy of Copper of the American Institute of Mining & Metallurgical Engineers.

He is also a member of Phi Lambda Upsilon and Sigma Xi honorary societies.—Ross C. Purdy

PROGRESS AND SECURITY

To insure industrial progress and security one must employ research, education, and coöperation For ceramic corporations and persons, the American Ceramic Society is the means and opportunity at the lowest cost to secure these essentials to progress and security.

To make this coöperative enterprise of more value to you there must be more persons and more corporations actively participating in its activities and in its financing.

Here is our 1936 record. Four months are history. What shall the record be in the remaining eight months?

MEMBERSHIP STATUS

Members Paid		Deferred	Subscriptions	Monthly Sales	Total Circulation
Personal	Corporation				
December 31, 1935					
1248	187	26	488	225	2174
April 30, 1936					
1273	178	66	483	200	2200

ENAMEL DIVISION

Report of the Committee on Data

After due consideration, the Committee feels that a handbook of information on enamels would be a desirable publication. The need is not as great as it was a year ago because of the publication of A. I. Andrews' book, Enamels (*Ceram. Abs.*, **14** [7] 158 (1935)), which contains an excellent collection of tables. But undoubtedly there are many other bits of information useful to enamelers which could be included in a handbook of data on enamels.

It is difficult to gather from the literature all of the material which should go into such a collection. The Committee feels that, if the Enamel Division wishes the publication of such a book, the coöperation of every member of the Division is essential in order to produce the best possible data book.

To aid in presenting its ideas, the Committee has had mimeographed an outline of the material which might be included in such a handbook together with a questionnaire.

The present Committee on Data recommends to the Enamel Division that copies of the outline and questionnaire be sent to each member of the Enamel Division and that, from the information thus obtained, a handbook of data on enamels be assembled by the 1936 Committee on Data. The Committee also recommends that the completed handbook be published by the Enamel Division or by such means as the rights and privileges of the Division permit.

—C. R. Amberg, *Chairman*

Your Ceramic Library Additions

1.	Journal of Original Researches (400 pages)	$10.00
2.	Abstracts of World-Wide Ceramic Literature (400 pages)	$10.00
3.	Applied Research Reports and Notes on Ceramic Research and Education	$ 5.00
	Total	$25.00

50% discount to personal members of the American Ceramic Society.

A Bargain Unusual—A Profit Not to Be Lost

NEW MEMBERS

Personal

BRADLEY, ALAN L., Steetley Lime & Basic Co., Ltd., Worksop, Notts., England; chief chemist.
BROWN, HORACE T., 1408 Landis Ave., Vineland, N. J.; chief engineer, Kimble Glass Co.
DUNBECK, NORMAN J., Eifort, Ohio; manager, Eastern Clay Products, Inc.
ELLERTON, HUGH, 56 High St., Newchapel, Stoke-on-Trent, England; ceramic chemist.
GOLDSCHMIDT, VICTOR M., Trondhjemsveien 23, Oslo, Norway; director, Geological Museum, and professor, University of Oslo.
INGERSOLL, HARRY, 4514 S. Van Ness Ave., Los Angeles, Calif.; Pacific Coast representative, Porcelain Enamel & Mfg. Co., Baltimore, Md.
JOHNSON, G. A., 1129 Walnut St., Dover, Ohio; superintendent, Robinson Clay Products Co.
KOENIG, E. W., Erwin, Tenn.; chief chemist, Consolidated Feldspar Corp.
KREIDL, IGNAZ, Schwarzenberg Platz 5a, Vienna, Austria, Vereinigte Chemische Fabriken, Kreidl, Heller & Co.
KROGH, ANKER E., Brown Instrument Co., Philadelphia, Pa.; ceramic application engineer.
LYONS, OKEY A., 965 Tufts Ave., Royal Oak, Mich.; foreman, Champion Spark Plug Co. (Ceramic Division).
LUMMIS, J. G., 205 Clinton Heights Ave., Columbus, Ohio; district sales manager, A. P. Green Fire Brick Co.
MAGNUSON, J. W., 1151 South Ogden, Denver, Colo.; Western Feldspar.
MERCK, WALTER J., 115 Locust Hill Ave., Yonkers, N. Y.; refractories engineer, M. W. Kellogg Co.
MILLIGAN, LOWELL H., 1 Howatson Way, Worcester, Mass.; research chemist, Norton Co.
PORTER, GARNETT H., 7 Oatman Terrace, Pittsfield, Mass.; chemical engineer, Pittsfield Works, General Electric Co.
ROBINSON, G. R., 1536 Maple Ave., Zanesville, Ohio; Hocking Valley Brick Co.
TAYLOR, CHARLES H., Waller St., Portsmouth, Ohio; manager, Charles Taylor Sons Co.
WARDLEY, THOMAS, Westpoint Rockware Ave., Greenford, Middlesex, England; chief engineer and works manager, British Hartford-Fairmont Syndicate & Rockware Glass Syndicate.
WILLSON, B. W., 1523 N. Monroe Ave., Mason City, Iowa; ceramic engineer, Mason City Brick and Tile Co.
WRIGHT, GEORGE C., 3467 Clearfield Ave., Pittsburgh, Pa.; service manager, Vitro Mfg. Co.

Student

MOORE, LYMAN M., University of Illinois.
NAPIER, J. B., Georgia School of Technology.

Membership Workers' Record

Personal			
R. E. Arnold	1	R. N. Long	1
R. S. Bradley	1	Louis Navias	1
J. H. Chesters	1	A. J. Strod	1
P. W. Dager	1	H. G. Wolfram	1
A. N. Finn	1	Office	7
J. R. Green	1	Total	21
F. A. Harvey	1	**Student**	
William Hugill	1	R. K. Hursh	1
V. V. Kelsey	1	W. H. Vaughan	1
Werner Kreidl	1	**Grand Total**	**23**

Energy + Persistency + Continued Study + Constant Cultivation with your Fellow Ceramists = Success ∴ YOU + The American Ceramic Society

ROSTER CHANGES DURING APRIL *

Personal

ALLY, ABDE, c/o Dr. Khurshed Husain, Kunta Road, Hyderabad, Deccan, India. (Sheffield, England)
AYDELOTT, ELLIOTT C., 615 Hinman Ave., Evanston, Ill. (Dayton, Ohio)
BAKER, JULIUS, 1131 Superior Ave., Dayton, Ohio. (Columbus, Ohio)
BETZ, GEORGE C., The Foote Mineral Co., 1609 Summer St., Philadelphia, Pa. (Trenton, N. J.)
HAINSFURTHER, R. M., 1013 Oregon Ave., Tarentum, Pa. (Creighton, Pa.)
HAMMER, GÜNTER, Fleschstrasse 18, Wilhelmsburg a./Tr., Austria. (Bunzlau, Germany)
KAISER, CARL E., 38 Columbia Ave., Mansfield, Ohio. (Columbus, Ohio)
KAY, WILLIAM T., 115 West Boulevard, Mexico, Mo. (New York, N. Y.)
KEITH, WENDELL P., Wilmette, Ill. (South Amboy, N. J.)
NAVRATIEL, HANS, Friedrichestr. 6, Lauf b/Nürnberg, Germany. (Berlin-Charlottenburg, Germany)
REIMER, JOHN J., Penn Tile Co., Aspers, Pa. (Hamburg, N. Y.)
REYNOLDS, OWEN J., Corning Glass Works, Corning, N. Y. (Addison, N. Y.)
RUSS, JOHN T., National Grinding Wheel Co., N. Tonawanda, N. Y. (Niagara Falls, N. Y.)
SCHURECHT, H. G., 16 Franklin St., Matawan, N. J. (Rahway, N. J.)
SHERWOOD, ROBERT F., United Feldspar Corp., 10 East 40th St., New York, N. Y. (Hamilton, Ont., Canada)
SMITH, ROY G., Box 2285, Houston, Texas. (Fort Worth, Texas)
SPENCER, ERNEST H., Cerro De Pasco Copper Corp., La Oroya, Peru, South America. (Roseville, Ohio)
STEVENS, JOE E., 5601 S. Boyle Ave., Vernon, Calif. (Huntington Park, Calif.)
TURNBULL, GALE, Vernon Potteries Ltd., Vernon, Calif. (Sebring, Ohio)
WALKER, FRANCIS W., JR., 105 W. Second St., Frederick, Md. (Beaver Falls, Pa.)
WILLIAMS, ARTHUR E., 810 Columbia Terrace, Peoria, Ill. (Warren, Ohio)
YOUNG, DAVID A., 6207 West Park, St. Louis, Mo. (Wayne, Neb.)
YOUNG, DAVID H., Georgia Kaolin Co., Dry Branch, Ga. (Rockmont, Ga.)

Student

HOH, SHAI-KWONG, c/o Trustees, Lingnan University, 150 Fifth Ave., New York, N. Y. (Alfred University)
PETERS, JOSEPH D., 2710 Main St., Bridgeport, Conn. (Ohio State University)
SCHIEFFERLE, JAMES, 3721 South St., Wesleyville, Pa. (University of Alabama)

* Address in parentheses is the old address.

LOCAL SECTION NEWS

PITTSBURGH SECTION

H. A. Ambrose of the Gulf Research Laboratory, addressed the members of the Pittsburgh Section of the American Ceramic Society, March 17, on "The Use of Clay in Drilling Oil Wells."

This talk was delivered less than twenty hours before all except emergency activities in Pittsburgh came to a stop due to the recent flood. In spite of the threatening conditions a representative group of ceramists heard Dr. Ambrose at Mellon Institute.

Use of Clay in Drilling Oil Wells

The use of clay slip as it is pumped into wells being sunk by the rotary drilling method was described. The clay slip floats cuttings to the surface, and acts as a temporary casing in sealing off water, oil, and gas veins. The *p*H of the slip is under control as must be its consistency and density. Temperatures of more than 212°F are sometimes encountered in deep-well drilling. Bubbles will tend to accumulate in the slip, unless removed, and have been known to lower the density to a point where the subterranean gas pressures can no longer be resisted. Disastrous "blow outs" followed by gas explosions then occur. Lives may be lost, machinery is wrecked, and the cost of completing the well goes up tremendously.

The difficulties of drilling through "heaving shale" were described. In "dritt drilling" a well, started on land, may be caused to change its direction and tap oil horizons well beneath the waters of the sea.

Dr. Ambrose's talk was enriched by excerpts from his actual experiences in the oil fields, where tobacco chewing and some facility in the use of expletives are not considered to be social errors.

One of the most spirited discussions of recent times followed the conclusion of the address. This could perhaps be attributed to the effective manner in which Dr. Ambrose brought out the drama accompanying the application of science to man's stark struggle with nature.

—D. G. Bennett, *Secretary*

Victor Hicks Addresses Pittsburgh Section

Victor Hicks of the University of Pittsburgh, addressed the Pittsburgh Section of the American Ceramic Society, April 14, on "The Applications of X-rays in the Ceramic Industry." Forty members were present.

Applications of X-rays in the Ceramic Industry

Extensions of the early applications of industrial radiography to the inspection of welds have given a satisfactory method of physical testing which, when properly employed, should lend confidence to the use of welded construction in ceramic factories and equipment. Radiography may be used to reveal completely the location and extent of internal cracks, voids, foreign objects, and regions of inhomogeneity in brick and cast ceramic materials. The coefficient of viscosity and the surface tension of molten ceramic materials may be determined radiographically by simple procedures.

The principles and technic of X-ray diffraction analysis were described briefly. X-ray diffraction methods, applied to certain ruby glasses, have shown that a solid solution of cadmium sulfide and cadmium selenide may be responsible for the color. By similar methods, the opacity of certain soda-lime-silica-fluoride glasses has been attributed to either quartz or cristobalite, depending on the thermal history; if alumina is added to these glasses, tridymite appears with similar heat treatment. Chromic oxide has been found in this way to crystallize from certain enamel glasses, but not cobalto-cobaltic oxide. The theories of Randall, Rooksby, and Cooper, of Zachariasen, and of Warren, concerning the atomic arrangements in a clear glass were discussed briefly.

—Dwight G. Bennett, *Secretary*

PACIFIC NORTHWEST SECTION

The Pacific Northwest Section of the American Ceramic Society held a joint meeting with the Local Section of the American Institute of Mining and Metallurgical Engineers on April 20. Oliver Ralston, Supervising Engineer, Nonmetallics Station, U. S. Bureau of Mines, New Brunswick, N. J., spoke on "Nonmetallics."

Mr. Ralston was former superintendent of the Northwest Experiment Station at Seattle, Wash., and was also in general charge of the Bureau of Mines activities on the Pacific Coast with headquarters at the Berkeley Station. Although his experience and training have been mainly devoted to metallurgical problems, he is giving valuable assistance to nonmetallics in the fields of beneficiation of raw materials by froth flotation and his wide knowledge of the principles of physical and organic chemistry.

Mr. Ralston spoke of the numerous recent nonmetallic developments in North Carolina, the Bureau of Mines projects in the Spruce Pine kaolin purification, the studies of Portland cement at New Brunswick, recent developments in the limestone industry, and the new uses for vermiculite from Libbey, Mont.

Seventeen of the 42 persons present were representatives of the ceramic and nonmetallic industries near Seattle.

—Hewitt Wilson

CENTRAL OHIO SECTION

Robert B. Sosman, former physicist with the Geophysical Laboratory, Washington, D. C. and now with the United States Steel Corp. Research Laboratory, Kearny, N. J., addressed the Central Ohio Section of the American Ceramic Society on May 1 at Battelle Memorial Institute, Columbus, Ohio. His subject was "Pyrometric Cones and the Measurement of High Temperatures." Ninety-six members and guests attended this meeting.—H. E. Simpson

AMERICAN CERAMIC SOCIETY SPONSORS EXHIBITION OF AMERICAN CERAMICS IN DENMARK

Sponsored by the American Ceramic Society, a representative exhibition of American ceramics assembled by the Syracuse Museum of Fine Arts, Syracuse, N. Y., will be shown at the Kunstindustri Museum, Copenhagen, Denmark. Selected pieces from the four National Robineau Memorial Ceramic Exhibitions, held annually in Syracuse, will be included.

Richard F. Bach, Metropolitan Museum of Art, New York, N. Y., is Chairman of the Jury of Selection. R. Guy Cowan, Onondaga Pottery Co., Syracuse, N. Y., will represent the Art Division of the American Ceramic Society on the jury.

This exhibition has been planned with the coöperation of Ruth Bryan Owen, American Minister to Denmark, and Meta Lassen, Los Angeles, Calif., who brought the Danish Art Exposition to the United States in 1927.—A.W.O.

NOTES AND NEWS FOR CERAMISTS

KERAMOS CONVOCATION WELL-ATTENDED

Over one hundred active and alumni members of Keramos, national professional ceramic engineering fraternity, were present at the biennial convocation held in Columbus, Ohio, during the Annual Meeting of the American Ceramic Society.

Reports of the various officers and committees indicated the fraternity was doing excellent work in promoting the professional status of ceramic engineers, ceramic education, and research. The report of the treasurer also showed the fraternity to be in a healthy financial condition.

The Keramos banquet, held at the Fort Hayes Hotel, was a most enjoyable affair with F. L. Steinhoff, retiring president, acting as toastmaster. During the affair porcelain plaques, representing the badge of the fraternity, were presented to President Steinhoff and Ross C. Purdy by the Illinois Chapter.

Following the banquet, a model initiation was put on by the officers of the Ohio State Chapter.

The newly elected officers for the biennium 1936 to 1938 are as follows:

President, R. E. Birch, Harbison-Walker Refractories Co., Pittsburgh, Pa.

Vice-President, H. G. Wolfram, Porcelain Enamel and Mfg. Co., Baltimore, Md.

Secretary, C. M. Dodd, Missouri School of Mines, Rolla, Mo.

Treasurer, S. R. Scholes, New York State College of Ceramics, Alfred, N. Y.

Historian and Editor, A. F. Greaves-Walker, University of North Carolina, Raleigh, N. C.

Representatives of all chapters and sub-chapters except the University of Washington were present at the convocation.

It was announced that during the past biennium the following were made honorary members of the fraternity:

C. Forrest Tefft, Columbus, Ohio, J. W. Whittemore, Blacksburg, Va., and Hewitt Wilson, Seattle, Washington.—A. F. Greaves-Walker

Dinnerware Booklet Compiled

Better Buymanship, No. 18: "Dinnerware," recently published to guide prospective purchasers of ceramic tableware, lists *The Journal of the American Ceramic Society* and *The Bulletin* in its references, and extends acknowledgement to several members of the American Ceramic Society for their assistance in securing the information printed.

Among the Society members who are listed in the acknowledgements are the following: Arthur E. Baggs, Ohio State University, Columbus, Ohio; A. V. Bleininger, Homer Laughlin China Co., Newell, West Va.; George H. Brown, Rutgers University, New Brunswick, N. J.; Harry A. Brown, Lenox, Inc., Trenton, N. J.; Ross C. Purdy, General Secretary of the Society; Frederick H. Rhead, Homer Laughlin China Co.; Charles L. Sebring, Sebring Pottery Co., Sebring, Ohio; and Arthur S. Watts, Ohio State University.

Information of interest to the trade, retailers, buyers, and the consumer has been compiled by Burr Blackburn, Bernice Dodge, and Martha B. King. Consumers are told how to distinguish quality and values.

The price of the booklet is two for five cents and it is available in lots of fifty or more for study groups at one cent each. Household Finance Corp., 919 North Michigan Ave., Chicago, Ill., is the publisher.

Early American Glass Exhibited in Brooklyn

In connection with the 1936 Exhibition of American Glass Industries, held at the Brooklyn Museum, March 21 to April 20, 1936, a small group of early American glass was shown. An unusually complete set of glassblower's tools, including two blow pipes, one for heavy work and one for light work, a "second block," a "pipe pick" for knocking the hardened glass off the pipes, a punty rod, a pair of calipers, shears for cutting bottle necks, a clay block for smoothing out the glass vats, and a piece of flint glass made in a New York factory were exhibited. J. H. Edgette and Helena Penrose, New York, N. Y., lent the tools.

Elizabeth Haynes, Curator of the American Rooms, arranged this section of the Exhibition.—Grant H. Code

MEETINGS SCHEDULED

Ohio Ceramic Industries Association

Refractories and Heavy Clay Products Divisions

The Refractories Division and Heavy Clay Products Division of the Ohio Ceramic Industries Association will hold their Annual Spring Meeting at Ohio State University, May 27. These Divisions will meet in a joint session, following which each will hold a technical meeting as usual.

The General Session reports to be given are as follows: C. E. Bales, Ironton Fire Brick Co., Ironton, Ohio, Chairman, Public Relations Committee, will report on the legislative situation, both state and federal, as it affects the ceramic industry.

Emery R. Hayhurst, State Board of Health, who has made an exhaustive study of the subject, will report on "Silicosis."

J. O. Everhart, Ohio State University Engineering Experiment Station, will present the final reports on "Metal Wear Research."

Programs of the technical sessions of each Division will be announced later. H. M. Christman, Massillon Refractories Co., Massillon, Ohio, is Chairman of the Refractories Division. R. K. Beck, Cleveland, Ohio, is Chairman of the Heavy Clay Products Division.

White Wares Division Meets May 28

The Annual Spring Meeting of the White Wares Divison of the Ohio Ceramic Industries Assn., will be held at East Liverpool Country Club, East Liverpool, Ohio, May 28.

Among the subjects to be discussed at this Meeting are the following:

(1) "Use of Syenite and Spodumene in Place of Feldspar in Bodies and Glazes," by C. J. Koenig, Ohio State Univ., Eng. Expt. Sta.

(2) "Report on Research in the Development of a One-Fire Size," by W. H. Earhart, Ohio State Univ. Eng. Expt. Sta.

Arthur A. Wells, Homer Laughlin China Co., is Chairman of this Division.—H.E.N.

Fourth Conference on Glass Problems

Sponsored by the Department of Ceramic Engineering, University of Illinois, and the Chicago Section of the American Ceramic Society, the Fourth Conference on Glass Problems will be held at Urbana, Ill., June 5 and 6.

The tentative program is as follows:

1. "Temperature Measurement and Control in the Glass Industry" by A. E. Krogh.
2. "Notes on Heat Transfer in Glass Tanks" by C. Cone.
3. "Testing of Glass Containers" by John M. McCormick.
4. "Identification of Stones in Glass" by C. L. Thompson.
5. "Some Characteristics of Fine Glass Fibers" by John H. Thomas.
6. "Batch Separation Studies" by D. D. Burress.

Additional papers on the following topics have been promised: "Electric Melting of Glass" and "Formation of Seeds." Those desiring a copy of the complete program when it is issued may secure one by writing to the Dept. of Ceramics, University of Illinois, Urbana, Ill.

Clay Products Plant Operators Conference

A conference for operators of clay products plants will be held at Urbana, Illinois, on June 12 to 13, 1936, by the Department of Ceramic Engineering, University of Illinois. In response to requests, this meeting is planned for men who are directly concerned with plant operation, giving them an opportunity to discuss mutual problems. The papers will be presented by manufacturers, superintendents, and engineers on subjects of primary importance in plant operation of structural clay products and refractories. Discussion of these topics will be held.

Friday Afternoon, June 12

The Production and Utilization of Power in Clay Products Plants

1. Steam Power Plant Problems
2. Effective Use of Electrical Power
3. The Use of Diesel Engines for Power Production

Friday Evening, June 12

1. Phenomena of Electrical Discharge

A special lecture and demonstration by C. T. Knipp, Department of Physics, University of Illinois, who is widely known, will consist of a series of demonstrations that will be extremely interesting to all who attend.

Saturday Morning, June 13

Drying of Clay Products

1. Basic Principles of the Drying Process
2. Operation and Control of Driers
3. Drying De-Aired Clay Products

Saturday Afternoon, June 13

Firing of Clay Products

1. The Effect of Heat on Clay Bodies
2. Operation and Control in the Firing of Periodic Kilns
3. The Use of Car Tunnel Kilns
4. The Firing of De-Aired Clay Products

The conference will be open to all who wish to attend and without fee. The complete program will be announced later. Further information may be obtained from the Dept. of Ceramic Engineering, Univ. of Illinois, Urbana, Ill.

CERAMIC SCHOOL NOTES

CERAMIC EXPERIMENT STATION AT NEW YORK STATE COLLEGE OF CERAMICS

The broad fundamental features of the new Ceramic Experiment Station which will be in operation the first of July, 1936, at New York State College of Ceramics, Alfred, N. Y., have been decided.

It is planned to operate this experiment station as a fourth department of the College of Ceramics. It will be known as the Research Department and will be directed by a department head under the administrative supervision of the Dean of the College.

The Ceramic Association of New York, through its Board of Directors, is to serve as advisory body to the Dean of the College. Through this arrangement the work of the Station will be directed in the best interests of the New York ceramic industry.

Research Programs

The general aspects of the research programs deal with work on ceramic raw materials and products of New York State. Samples will be gathered from all the ceramic deposits in the State and subjected to standard tests to determine the products that can be made with them and the best manufacturing procedure to use. This part of the program involves geologic work in collecting the samples, chemical work in analyzing them, and ceramic testing work in determining their ceramic properties and ceramic uses. In addition, fundamental scientific work on their basic properties and the alteration of these properties may be involved.

Another feature of the work will be engineering research on manufacturing operations to determine the best forming, drying, and firing procedures for the various classes of raw materials. All of this work is to be intimately connected with research on producing new products and reducing costs of manufacture.

Commercial testing will also be carried on in the Station. Provision is to be made for receiving orders from industrial plants for all kinds of ceramic testing. Charges will be made covering the costs of the tests. Tests for state agencies will be made without charge.

Progress reports on all work of the Station will be published in regular monthly bulletins sent to all New York ceramic companies. Another important feature of the work will be the writing of bulletins on such subjects as a history of the glass industry, a directory of the ceramic companies of New York, and others. This literature will occupy a secondary position in relation to the bulletins giving results of the testing and research.

—M. E. HOLMES, *Dean*

Special Summer Course in Colloid Chemistry

The Department of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass., has announced a five-week summer course in Colloid Chemistry beginning June 16. Ernst A. Hauser, Associate Professor of Chemical Engineering, is in charge of the course.

The fundamentals of colloid chemistry and physics, with special emphasis on colloid reactions in industry will be covered. The laboratory work will deal with the generally used methods for determinations and analysis of colloidal systems, including surface-tension measurements, sedimentation analysis, coagulation tests, production of dispersions, emulsions, and others. Training in microscopy as it relates to colloidal research will be given.

Harold E. Edgerton of the Dept. of Electrical Engineering will give lecture-demonstrations on the application of stroboscopic measurements in industry, including his high-speed motion picture technic. Those interested in special problems will be enabled to carry out original research under supervision. Evening lectures of the Course in Practical Spectroscopy given by G. R. Harrison of the Dept. of Physics are available to registrants in the Course in Colloid Chemistry.

Applications and correspondence should be sent to Ernst A. Hauser, Massachusetts Institute of Technology, Cambridge, Mass.—E. A. H.

WANTED: New Student Members for the American Ceramic Society

Ceramic Firms Exhibit at New York State College of Ceramics

Twenty New York ceramic concerns exhibited their products at the fourth annual St. Pat's Festival held March 26 and 27 at New York State College of Ceramics, Alfred, N. Y. The industrial exhibits supplemented the student demonstrations of the Open House, illustrating features of the ceramic industry which could not otherwise be displayed. The entire project was a student undertaking.

Glass blowing, demonstrated by the Steuben Division of the Corning Glass works, Corning, N. Y., was a popular feature of the Open House which was attended by a record crowd of over a thousand visitors. Student work included a large mural, designed and executed by students of the Ceramic Art Department under the supervision of Donald Schreckengost. It showed the winning of clay, its transportation, processing, and finishing as well as a central section picturing various phases of glass manufacture.

Other demonstrations included the operation of X-ray, petrographic, spectrographic, and chemical apparatus; throwing on the potter's wheel, turning, jiggering, pressing and casting; kiln setting and firing and the use of heat indicating and recording instruments.

Students exhibited phases of the manufacture and composition of glass in addition to a demonstration of glass testing apparatus. Clay paperweights and glass ash trays, made by students, were sold as souvenirs and their manufacture used to show the pressing of clay and the

molding of glass. St. Patrick was impersonated by Major Lampan, senior engineer.

This Festival and Open House was initiated by Dean Holmes four years ago and has been held annually since.

Wilber Stout Receives Honorary Degree

Wilber Stout, Ohio State Geologist, is one of four men who will receive honorary degrees from Mount Union College at its Ninetieth Annual Commencement, June 16, according to a recent announcement from the College. He will be made a Doctor of Science.

"WANTED CERAMIC ENGINEER"

with at least ten years' plant experience who has had extensive experience preparing materials, forming in automatic machines and firing vitreous bodies made of 90 to 100% talc. Ability to control sizes essential. Must have experience; we do not want to experiment. In answering give complete details of experience, education, salary, etc. Plant is near Pittsburgh. Address American Ceramic Society, 2525 N. High St., Columbus, Ohio. Box 147 F.

COMMUNICATIONS—CERAMIC HISTORY

EMPLOYMENT OF CERAMIC GRADUATES

Is there an oversupply of ceramic graduates by the ceramic colleges or an underconsumption of them by the ceramic industries?

Data on the unemployment of engineering graduates in general were recently published by M. M. Boring of the General Electric Company.[1] He reported that among 8524 engineering graduates of the years 1931, 1932, 1933, and 1934, 59% were satisfactorily placed in the industry; 2½% were teaching; 16.7% were in stop-gap jobs; 18.5% were unemployed; and 4.26% were in post-graduate work. No definite data are available on unemployment specifically among ceramic graduates but, in the opinion of many, the data given above for engineering in general are fairly representative of the ceramic situation. If this opinion is correct, the situation is not satisfactory. Education is being handicapped and the ceramic industry is permanently losing promising young men who could contribute much to the industry.

That the ceramic institutions are not flooding the country with ceramic graduates is indicated by the data[2] on enrollment at the mineral industries institutions of the United States (see the table).

Although the data may be slightly conservative, it is significant that this year only about 60 ceramic engineers will be graduated in this country. There will be almost four times as many mining engineers graduated, and almost three times as many graduates in metallurgy, and in petroleum and natural gas engineering. Certainly the data do not indicate excessive concentration of engineering training in ceramics.

It is recognized that not all graduates are deserving, but most of them are. The process of elimination weeds out the weaklings to a large extent. To be a graduate of a recognized ceramic institution, he must be much above the average. He must first graduate from a high school. He must have the incentive to qualify as an engineer. Some colleges do not admit him unless he ranks scholastically in the middle or upper third of his high-school class. He must have the perseverance and interest to work four years in college and meet high scholastic standards. Some ceramic colleges require a grade point index of 0.5 for freshmen and 1.0 for graduation. These are very high standards. The data given above show the high mortality in college. About one out of four get through and they must have demonstrated superior quality of character to be recommended for ceramic jobs. This college training has cost the state about $1500 and the graduate, himself, about $2500.

There is no overproduction of ceramic graduates by the colleges, but there is an underconsumption of them by the industries.

ENROLLMENT BY COURSES, 1934 TO 1935 (UNITED STATES)

	Freshmen	Sophomores	Juniors	Seniors	Total undergraduates	Graduate students	Grand total	Candidates, Bachelor degrees
Mining	545	406	285	235	1471	55	1526	224
Metallurgy	234	234	194	182	844	93	937	174
Petroleum and natural gas	520	322	236	179	1257	29	1286	177
Ceramics	221	147	90	65	523	36	559	60
Geology	146	127	106	83	462	62	524	77
Fuel technology	19	18	15	15	67	10	77	15
Special students							102	
Totals	1685	1254	926	759	4624	285	5011	727

[1] M. M. Boring, "College Graduate Placement Survey," *Jour. Eng. Ed.*, p. 198 (Nov. 1935).

[2] William B. Plank, "Mining Schools Enjoying Record Enrollment," Reprinted from *Mining & Met.* (Nov., 1935).

Fred Deurelein (seated at the glassworker's bench), Sam Gullo (blowing through the iron), and Frank J. Hultzman (standing) are shown above as they reenacted the scene at Corning Glass Works during the first attempts in 1879 at Corning to blow glass bulbs for Thomas A. Edison's early incandescent lamps.

MANUFACTURE OF EARLY INCANDESCENT LAMP BULBS AT CORNING*

By George B. Hollister

When Thomas A. Edison was in the midst of the researches which culminated in his perfection of the incandescent lamp, he came to a point where it was necessary for him to secure suitable glass bulbs in which to mount his filaments. In his own laboratory, he had set up a small glassworking equipment which was adapted for his earlier experiments and by means of which he had convinced himself that glass could be used successfully as an envelope for his lamps. But in this laboratory he had neither the skill nor the capacity to furnish the bulbs he needed for his work, standardized in shape and size.

He was therefore casting about for a more adequate supply when in 1879 officials of the Corning Glass Works happened to learn of his needs. As a result of this information, which had come quite casually, a meeting was arranged with Mr. Edison to discuss the matter. At this conference a number of matters relating to the manufacture of lamps were considered, but most prominent among them were the composition and resulting quality of a glass which would be suitable for bulbs, particularly as to its adaptability for processing in the flame, to insure the operation of the sealing-in of his platinum leading in wires and also to insure the success of first attaching, and later melting off, the small glass tube at the top of his lamp, through which he expected to accomplish his exhaust operation.

It so happened that the Corning Glass Works had for years specialized in the manufacture of lead glasses as a basis for its fine cut glass and other ware, and when it was shown that some of these glasses could be successfully adapted to the processes of lampmaking, Mr. Edison agreed to send a representative to Corning to secure an initial supply of bulbs to be made from Corning's lead glass.

The manufacture of incandescent bulbs as a commercial product had not at that time been developed. There was no precedent and no established manufacturing technique as a guide to the work. So when it was settled that an

* Received March 3, 1936. George B. Hollister is Vice-President of Corning Glass Works, Corning, N. Y.

attempt would be made to produce the bulbs at Corning, it was decided to make use of the blowing skill which was there employed in making thin-walled ware, especially since this skill was in daily use and was thoroughly familiar to the workmen and since the articles produced by it had many points of similarity to the needed bulbs.

On the day appointed, Mr. Edison's representative arrived in Corning and brought with him a sketch of the article he desired, and one of the Glass Works' most skillful shops was assigned to him for the trial. The first bulbs were blown "free hand," that is, without a shaping mold. But as the hours of that first day's trial progressed, another method was tried. On the end of their blow-irons, the men drew out short tubes with closed outer ends. The closed ends of these tubes were then reheated in the flame and, when the glass was hot enough, the blow-irons carrying the tubes were placed on the horizontal arms of the "gaffer's" bench and slowly rolled by him back and forth, while a boy blew into the opposite end of the iron. (See accompanying illustration.) The gaffer meanwhile measured with his calipers the expanding bulb on the end of the tube, and when the bulb was sufficiently blown out, the gaffer, with a quick movement, snatched the blow-iron away from the lips of the blowing boy and the bulb was finished. There were 165 bulbs, satisfactory to Mr. Edison, made on that first day, and the record states that "it took all day to make them."

Of course, this process was necessarily slow and costly and introduced far too much uncertainty in the shape and wall thickness of the resulting bulbs, and yet these early bulbs, crude as they were by later standards, gave Mr. Edison material for further steps in the development of his lamp.

The Glass Works, however, realizing the possibility of the future growth of a new industry, at once seriously attacked the problem of cheaper and more accurate manufacturing methods. The free-hand blowing method was discarded. Cast iron mold-shells, hinged to open laterally, were then developed, and these shells were lined with Babbitt metal to conform to the size and shape of the finished bulb. The Babbitt lining was coated with a thin film of paste made from a mixture of boiled linseed oil and very finely powdered charcoal, which was afterward heated and dried in place to a rigid film. The practice was to dip the mold in water just before each bulb was blown. As the hot glass expanded under air pressure, it vaporized the moisture which the mold coating retained after being dipped, so that the revolving bulb was cushioned by a thin layer of water-vapor, and it was largely because of this steam cushion or "seat" that the bulb emerged from the mold with its beautiful brilliant outside finish. This method, early introduced, which made use of so-called "paste" molds, continued for many years and is still used in principle, though necessarily somewhat modified by the later introduction of automatic bulb-blowing machinery.

The accompanying photograph was taken in 1921, forty-two years after the first bulbs were made for Mr. Edison, in an effort to reënact the scene that took place on the day of that first trial. The picture shows the blowing of a bulb, by the method then used, of first drawing, or "running out" a short tube of glass on the end of the blow iron, then reheating the end of the tube and blowing out the heated end into a bulb. It is of added interest to know that two of the men shown, Frederick F. Deurelein and Frank J. Hultzman, were members of the "shop," or working unit, which produced the original bulbs. They were both boys at the time of the early trial, having entered the employ of the Company in 1876, and today (1936) they are still in active service. They are now the only surviving members of the original "shop." Fred Deurelein is shown seated at the glassworker's bench, calipers in hand, ready to measure the size of the expanding bulb, "Yank" Hultzman is standing at the right; Sam Gullo, a more recent workman, kneeling, blows through the iron.

CORNING GLASS WORKS
CORNING, NEW YORK

POTTERY, ITS HISTORY AND TECHNIQUE*

BY HENRY P. MCILHENNY

A comprehensive exhibition of pottery was shown at the Philadelphia Museum of Art from March 28 to April 27, 1936. Drawn chiefly from the rich reserves of the Pennsylvania Museum of Art and the University Museum, almost every phase of the potter's art was displayed, a history, recorded in clay, of man's progress from the prehistoric Egyptian and Babylonian cultures to present-day civilization.

The pottery was chosen, with the aid of Edmund de Forrest Curtis of the School of Industrial Art, to cover both its technical and historical development. Consequently, a display of raw materials, tools, methods, and processes clarified and explained the chronological sequence.

* Received April 8, 1936. Henry P. McIlhenny is Assistant Curator of Decorative Arts, Pennsylvania Museum of Art, Philadelphia, Pa.

Ancient Pottery

Of all the arts, that of the potter is perhaps the most traditional. In Egyptian mythology Num, the directing spirit of the Universe, is said to have molded Man on his wheel from dark clay. It is certain that wherever clay was found prehistoric men became potters by sheer force of need, and the potter's craft must have started soon after the discovery of fire. At first useful articles such as bowls for storing food were made, but as the ages rolled by fired clay was used for an endless variety of purposes. Owing to the fact that fired clay can not be destroyed by the elements, many of our records of early cultures have been preserved only in this medium. Evidence of this was shown in the first gallery of the exhibition in the brick of ancient Egypt and Babylonia. Even the fascinating cuneiform letter with its envelope of clay remains almost intact. Man's natural instinct to find artistic ex-

Part of the first gallery, with some of the Greek and South American pottery, is shown in this photograph.

pression is shown on some of the sherds excavated at Tell Billa, which range in date from B.C. 3100 to B.C. 1500. The incision of lines in the soft clay, painting in colored clays, and polishing are the earliest form of decoration. This direct way of working without glaze has produced many fine results, as the ware of ancient Babylonia, South and North America, and Egypt testify.

As civilization progressed, and vessels that would hold liquids became necessary, the use of a transparent glaze arose. It was the Egyptians who first learned to melt a surface of fusible materials on the body of the clay. This great forward step was seen in the blue faience canopic jar made for an Egyptian tomb about B.C. 1250 lent by the University Museum. The ingredients for this seldom-rivalled copper blue were supplied by the Natron lakes and highly siliceous clays.

Greek and Persian Pottery

The group of Greek vases was outstanding. The culmination of the simple process of slip painting was represented in vases of unrivalled loveliness of line and proportion from the Sixth and Fifth Centuries B.C. The draftsmanship of the figures is of the highest quality. The small Tanagra figurine is surprisingly monumental.

There was also a case of Persian bowls and vases showing slip decoration covered with an alkaline glaze. It was Persia that gave the knowledge of glazing to the Chinese, and the Persian potters have left us some of the finest ceramics known. The iridescent quality, which is so attractive, derives from long contact with the earth.

Chinese Vases and Figures

The second gallery was chiefly given over to the work of the greatest of all potters, the Chinese. Starting with the Han period (B.C. 206 to A.D. 220) the earliest evidence of glazing in China is found in two wine vases from the Crofts Collection, given to the Museum by the late Charles H. Ludington. The Chinese were content for many years to use copper green and iron yellow for their glazes, as may be seen in the group of Tang (A.D. 618 to 906) horses, camels, and gods. Spirited in modeling, they rank among the finest sculpture of the East, and at the same time show the potter working in a monumental, sculptural style.

The group of Chinese pottery was outstanding for

The second gallery, containing a group of Chinese objects, including some Tang sculpture is shown here. The wall case to the right contains examples of delft, majolica, and Pennsylvania-German ware.

A selected group from the Fourth National Robineau Memorial Ceramic Exhibition, arranged through the courtesy of the Syracuse Museum of Fine Arts and circulated under the auspices of the College Art Association is shown above.

breadth and variety, as well as for high quality. The most interesting and the most elusive types, the peach-bloom, *sang de boeuf* and *flambé* glazes, were well represented. The large black hawthorne vase is a perfect specimen of the over-glaze type.

European Porcelain

The Jesuit priest, Père d'Entrecolle, wrote home to Europe of the wondrous ware of China in 1712 and 1722. This was the first account to reach western civilization, and all Europe began seeking the raw materials necessary to the manufacture of the Chinese hard porcelains. The English and French soft pastes were too fragile, and hard paste porcelain was first made at Meissen by Johann Friedrich Böttger. A red cup represents this important discovery.

England soon followed Dresden's lead, and the various Staffordshire factories vied with each other in making porcelain and bone china. Many interesting examples of Leeds, and other ware, were shown. The majority of these were lent by Mrs. E. Hollingsworth Siter.

Renaissance Pottery

There was also a group of majolica, chiefly Italian in origin, showing the typical Renaissance painted decorations of the Sixteenth Century. The dated pieces are of particular documentary value. The tonde by Andrea della Robbia from the Foulc Collection is of the typical French, Italian, and Spanish tin enameled, on-glazed type. The Hispano-Moresque luster plates were produced by mixing clay with vinegar before heating to a dull red heat. The red tones are from copper; the yellows, from silver.

American Ware

A large display of the Pennsylvania-German slip and graffito and incising techniques was also shown. This native American product ranks on a par with some of the European pottery.

Pottery of present-day America, the last phase in the historical and technical development, was typified by selected pieces from the Fourth National Robineau Memorial Ceramic Exhibition. The debt of present-day potters to the past is a heavy one, but they are to be praised for their effort to restore pottery to its former place of honor among the crafts. The articles cover a wide range, from miniature jars and chessmen to sculpture that is monumental in inspiration. The design, proportion, and color, the Egyptian blue predominating, are admirable. The facileness and breadth of contemporary originality, and invention is very reassuring to all those who value the pottery of the past.

Of particular interest was the work of students at the Pennsylvania Museum School of Industrial Art, so ably taught by Mr. Curtis. Their researches in re-creating the arts of the past are of great value.

Unglazed, under-glazed, on-glazed, color-glazed, and over-glazed—all types were shown in this unusually complete exhibition. The other processes of transmutations, crackles, and crystalline too were to be seen, and the descriptive labels prepared by Mr. Curtis were rich in information, both historical and technical.

Pennsylvania Museum of Art
Fairmount, Philadelphia, Pa.

EXCURSIONS PLANNED FOR VISITORS TO SECOND INTERNATIONAL CONGRESS ON GLASS

The outline of the excursions planned for the Second International Congress on Glass, to be held in London and Sheffield, England, July 2 to 11, 1936, has been received:

Excursions to Works in the London Neighborhood

(1) United Glass Bottle Manufacturers, Ltd., Charlton, and (2) Messrs. Rockware Glass Syndicate, Ltd., Greenford, Middlesex, manufacturers of bottles by automatic machinery.

(3) General Electric Company, Glass Works and Research Laboratories, Wembley, Middlesex, manufacturers by fully automatic processes of electric light bulbs, radio valves, and glass tubing.

(4) Messrs. James Powell & Sons (Whitefriars), Ltd., Wealdstone, Middlesex, makers of hand-made, plain and cut table glass, decorative glass of all descriptions, and stained glass for windows and mosaics.

Excursions

Visits to points of interest in London, in Oxford, where several colleges will be visited by the overseas visitors en route to Sheffield, and in Sheffield, have been planned by the London Section of the Society of Glass Technology and the British Organizing Committee.

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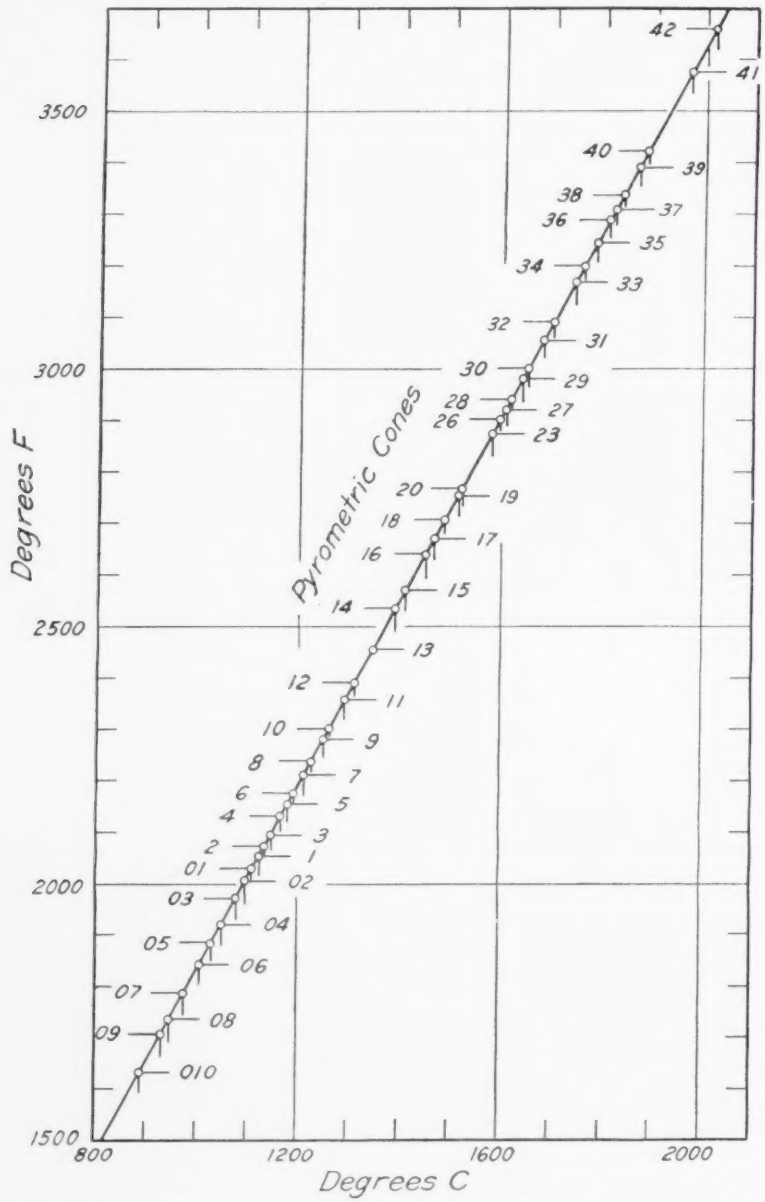
The profit and the savings resulting from having the latest information on ceramic art, science, and technology from all parts of the world, such as is obtainable from the activities of the American Ceramic Society, cannot be expressed in the realm's coin, but certainly it is much more than the Personal Dues of $12.50 and the Corporation Dues of (minimum) $25.00 annually.

It is axiomatic that the larger the personal and corporation support, the larger will be the informational returns to each member and the greater will be the stimulation of research and of the practical application of research.

It pays ceramists to secure a larger participation in and support of the American Ceramic Society.



Temperature Conversion Chart by Gilbert E. Seil, Technical Director, E. J. Lavino and Co., Philadelphia, Pa.

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Black Needle Antimony	Cobalt Sulphate	Nickel Sulphate	Uranium, Orange
Bone Ash	Copper Oxide	Rutile	Uranium, Yellow
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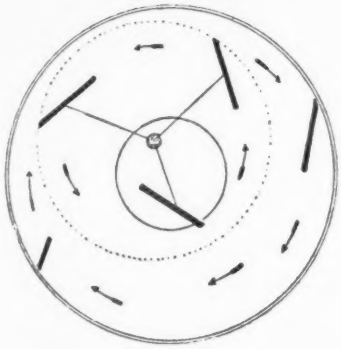

This diagram shows you why *"Lancaster"* Mixers insure you against heavy loss due to poor batch mixing.

Note the field of intensive action set up with the pan travelling in one direction and interior mixing unit moving in the opposite direction.

Also note the central discharge opening.

When your quality goes "off standard" who is the winner? Not yourself. For often this means sales at a loss . . . of profit as well as prestige.

Not your dealer. For sales of "seconds" only kill his profit on regular lines.

And poor, uncertain, careless batch mixes are often the cause of all the misfortune.

"Lancaster" Mixers strengthen a weak link in the production chain. Your chances of producing "off-standard" quality decrease amazingly.

"Lancaster" Mixers do the most thorough and still the speediest mixing job accomplished today. You owe it to your customers, as well as to yourself, to get the best batch mix possible.

There is a *"Lancaster"* Mixer to suit your formula and capacity.

Do you have our illustrated Bulletins 70-B and 70-E? If not, they are yours for the asking.

Mix Better and Quicker with a Lancaster

LANCASTER IRON WORKS, Inc., LANCASTER, PENNA.

BRICK MACHINERY AND MIXER DEPARTMENT, JAS. P. MARTIN, VICE PRES. & MGR.

MONTGOMERY PORCELAIN PRODUCTS CO.
Specializing in
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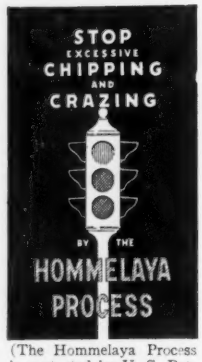

(The Hommelaya Process is protected by U. S. Patents No. 1,779,273; 1,805,143; 1,819,816; 1,962,617. Others pending.)

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Let Others Imitate—We Originate
PACIFIC COAST AGENTS
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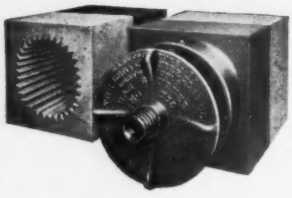
DFC
Gas Burner
for Kilns



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3. Your choice of Soda Ash graded for efficient use with any of the known commercial glass sands.
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Make Solvay your source of supply for
DUSTLESS CALCINED 98-100% POTASSIUM CARBONATE
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THE POTTERS SUPPLY COMPANY
EAST LIVERPOOL, OHIO

SECOND INTERNATIONAL CONGRESS ON GLASS

July 2 to July 11, 1936

LONDON AND SHEFFIELD

GLASS ◆ FUELS ◆ REFRACTORIES

For Program Outline of Meeting see the April issue of
The Bulletin of the American Ceramic Society, p. 168.

American Merchant sails from New York, June 19
arriving London, June 29.
Round trip rate $185.00.

S. S. Scythia (Cunard) sails from New York, June 19
arriving Liverpool, June 27.
Round trip rate $293.00.

John C. Hostetter, Corning Glass Works, Corning, N. Y., and Francis C. Flint, Hazel-Atlas Glass Company, Zanesville, Ohio, in charge of American participation.

Above exhibit displayed at the New York State College of Ceramics, Alfred, N. Y.

We manufacture all types of super refractories for the ceramic industries, and would be pleased to cooperate on your refractory problems.

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ANDREWS BLDG. **BUFFALO, N. Y.**

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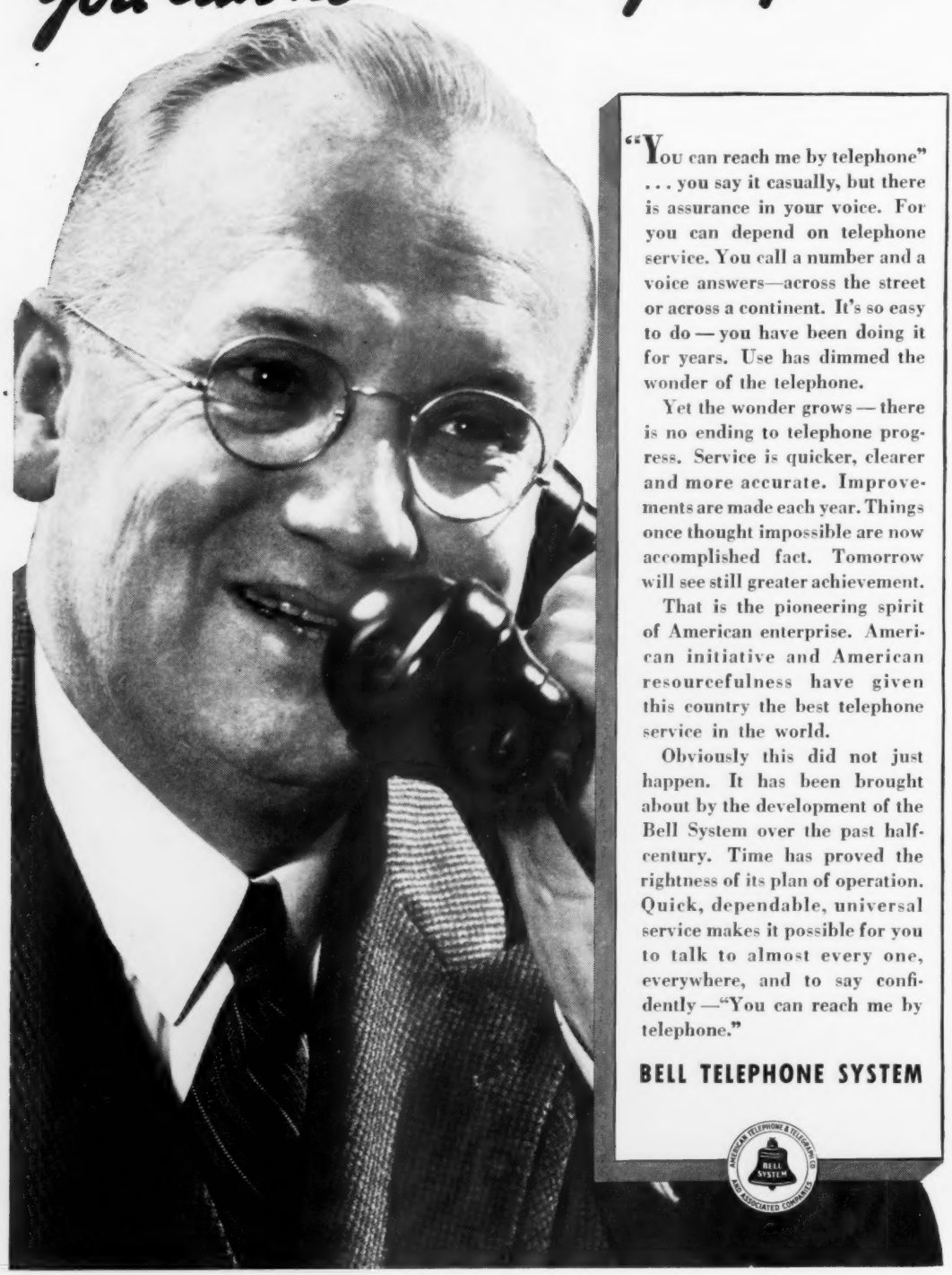
FINEST POTTERY CLAYS

"You can reach me by Telephone"



"You can reach me by telephone" . . . you say it casually, but there is assurance in your voice. For you can depend on telephone service. You call a number and a voice answers—across the street or across a continent. It's so easy to do — you have been doing it for years. Use has dimmed the wonder of the telephone.

Yet the wonder grows — there is no ending to telephone progress. Service is quicker, clearer and more accurate. Improvements are made each year. Things once thought impossible are now accomplished fact. Tomorrow will see still greater achievement.

That is the pioneering spirit of American enterprise. American initiative and American resourcefulness have given this country the best telephone service in the world.

Obviously this did not just happen. It has been brought about by the development of the Bell System over the past half-century. Time has proved the rightness of its plan of operation. Quick, dependable, universal service makes it possible for you to talk to almost every one, everywhere, and to say confidently—"You can reach me by telephone."

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AMERICAN TELEPHONE & TELEGRAPH CO. AND ASSOCIATED COMPANIES — BELL SYSTEM

H. C. SPINKS CLAY COMPANY

Miners and Shippers of

BALL SAGGER AND WAD CLAY

NEWPORT, KENTUCKY

May 1, 1936

Mr. Pete Potter
Comfortable Sanitary Pottery Mfg. Co.
Pottsville, Ohio

Dear Pete:

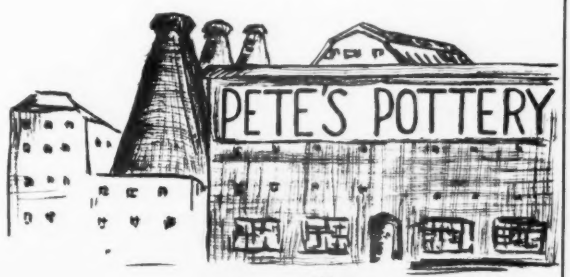
Really shouldn't take time to write to you today. We have been shipping out of our storage sheds all Winter and Spring but today is the day set to start mining, and we're busy spending money for supplies and improvements. Bought a dandy new truck that will haul eight tons at a trip.

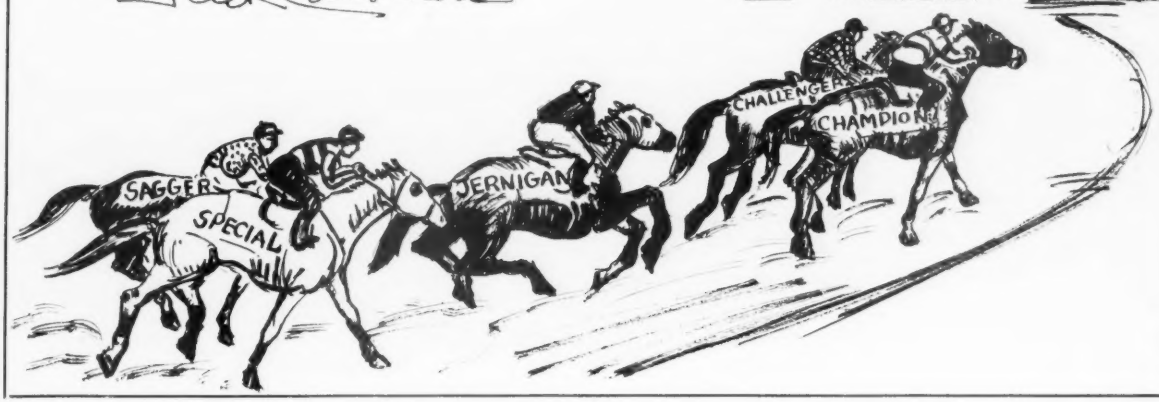
Furthermore, tomorrow is the day set for all the world to go back to Louisville to see the Kentucky Derby. Pete, study Derby history! Derbies are won by the best horses, trained and ridden by the most careful and capable trainers and jockies. Some of the good operators often use two or three horses and call it an entry. Then one helps the other. Colonel Bradley generally has an entry and he has won more times than anyone else, and sometimes finishes 1–2.

Take a tip from the winners. Use our CHAMPION and CHALLENGER mixture in your body, and JERNIGAN SPECIAL SAGGER (a mixture of three good clays) in your saggers and refractories! Both good entries! You can't lose! I may not see you in the crowd tomorrow, so

Good Luck and a Fast Track,

Dick Carothers





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For years M & T Sodium Antimonate has set the standard. The finest opacifier that modern methods can produce, it is always uniform, always pure. Every barrel of M & T Sodium Antimonate is exactly the same, both chemically and physically, as every other barrel.

And, this quality opacifier is more economical. Rejects, due to off colors, become rarities. Whites, whether blue white, cream white or some other hue, do not vary a shade from one year's end to the next where M & T Sodium Antimonate is used.

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